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NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

Sponsored by
NAVAL FACILITIES ENGINEERING COMMAND

A COMPENDIUM OF TENSION MEMBER PROPERTIES FOR INPUT TO CABLE STRUCTURE ANALYSIS PROGRAMS

April 1982

An Investigation Conducted by
Western Instruments Corporation
540 Maulhardt Avenue
Oxnard, California

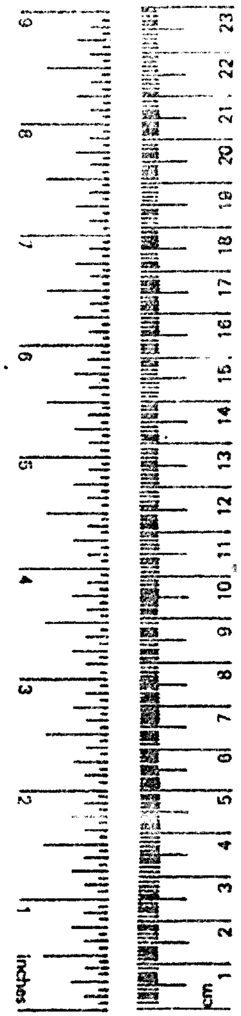
N68305-80-C-0004

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

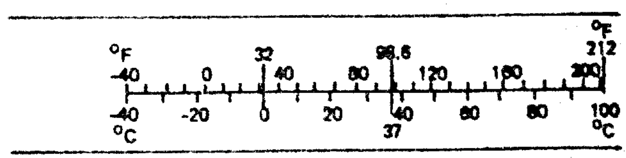
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13 10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Cable weight; cable strength; wire rope; chain; synthetic line; cable drag coefficients; cable statics; [illegible] dynamics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is a collection and condensation of cable properties used in computer simulations of cable dynamics problems. Data were taken from a variety of sources, and includes weight per foot (in air and immersed), elastic modulus, breaking strength, cross-sectional area, and drag and added mass coefficients. Cable types include chain, wire rope, synthetic and electromechanical.

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INTRODUCTION

This report is intended for use by ocean engineers analyzing and designing ocean cable structures. It is particularly structured to assist users of the SEADYN and DECEL1 computer programs for cable structure analysis. The tables and figures in this report will give the user a starting place to complete the initial design and analysis. Many of the properties given in this report are based on average and estimated properties (such as average breaking strength) rather than critical values (such minimum breaking strength). The final analysis should be completed using the limiting or critical mechanical and hydrodynamic properties of the structural elements as called out in designs based on the preliminary analysis. This may be an iterative process, but the important point is to use the values of cable properties which are most critical to the design and analysis before procuring the components.

SECTION I
PROPERTIES OF FLUIDS

KINEMATIC VISCOSITY

The SEADYN, DECEL1, and SNAPLD programs require the input of drag coefficients (C_d) which are determined from the Reynolds Number (N_R) and the shape of the structural member. Determination of N_R requires that the kinematic viscosity (ν) of the surrounding fluid be known. Table 1 gives ν for sea water and fresh water over the range of likely temperatures and Table 2 does the same for air at standard atmospheric pressure.

DENSITY

DECEL1 and SEADYN require the density of the fluid to be entered. The density of sea water can be taken as 1.99 $\frac{\text{lb-sec}^2}{\text{ft}^4}$ for $32 \leq {}^0\text{F} \leq 78$ and fresh water density is 1.94 $\frac{\text{lb-sec}^2}{\text{ft}^4}$ for $32 \leq {}^0\text{F} \leq 76$. Table 2 gives density of air at various temperatures.

TABLE I. KINEMATIC VISCOSITY OF FRESH WATER AND SEAWATER AT VARIOUS TEMPERATURES

Temperature, Deg F	Kinematic Viscosity of Fresh Water, $\frac{ft^2}{sec} \times 10^5$	Kinematic Viscosity of Sea Water, $\frac{ft^2}{sec} \times 10^5$
32	1.9231	1.9681
33	1.8871	1.9323
34	1.8520	1.8974
35	1.8180	1.8637
36	1.7849	1.8309
37	1.7527	1.7991
38	1.7215	1.7682
39	1.6911	1.7382
40	1.6616	1.7091
41	1.6329	1.6807
42	1.6049	1.6532
43	1.5777	1.6263
44	1.5512	1.6002
45	1.5254	1.5748
46	1.5003	1.5501
47	1.4759	1.5259
48	1.4520	1.5024
49	1.4288	1.4796
50	1.4062	1.4572
51	1.3841	1.4354
52	1.3626	1.4142
53	1.3416	1.3935
54	1.3212	1.3732
55	1.3012	1.3535
56	1.2817	1.3343
57	1.2627	1.3154
58	1.2441	1.2970
59	1.2260	1.2791
60	1.2083	1.2615
61	1.1910	1.2443
62	1.1741	1.2275
63	1.1576	1.2111
64	1.1415	1.1951
65	1.1257	1.1794
66	1.1103	1.1640
67	1.0952	1.1489
68	1.0804	1.1342
69	1.0660	1.1198
70	1.0519	1.1057
71	1.0381	1.0913
72	1.0245	1.0783
73	1.0113	1.0650
74	0.9984	1.0520
75	0.9857	1.0392
76	0.9733	1.0267
77	0.9611	1.0145
78	0.9492	1.0025
79	0.9375	0.9907
80	0.9261	0.9791
81	0.9149	0.9678
82	0.9039	0.9567
83	0.8931	0.9457
84	0.8826	0.9350
85	0.8722	0.9245
86	0.8621	0.9142

From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, February, 1977.

TABLE 2. DENSITY AND KINEMATIC VISCOSITY OF AIR AT STANDARD ATMOSPHERIC PRESSURE

Temperature T, °F	Density $\rho \times 10^3$ Lb-Sec^2/Ft^4	Kinematic Viscosity $\nu \times 10^4$ Ft^2/Sec
-40	2.94	1.06
-20	2.80	1.16
0	2.68	1.26
10	2.63	1.31
20	2.57	1.36
30	2.52	1.42
40	2.47	1.46
50	2.42	1.52
60	2.37	1.58
70	2.33	1.64
80	2.28	1.69
90	2.24	1.74
100	2.20	1.80

After: Fluid Mechanics with Engineering Applications, Daugherty, R.L., and Franzini, J.B., McGraw-Hill Book Company, 1965.

SECTION II
PROPERTIES OF FLEXIBLE TENSION MEMBERS

WEIGHT/UNIT LENGTH AND BREAKING STRENGTH

The cable dynamics and statics programs require inputs of the weight/unit length of the tension member. The user usually has an idea of the general breaking strength required and the type, material, and construction of the tension member desired. Tables of the most commonly used tension members have been enclosed to permit review and selection of the properties of the wire rope, synthetic line, chain, or cable which meets the design requirements.

Wire Ropes

Tables 3 to 15 give the breaking strengths and weights of the various constructions of wire rope manufactured by U.S. Steel which are usually used at sea and onshore. The weight in air of all ferritic and stainless steel constructions given can be converted to weight in sea water by multiplying the air value by 0.87. Those constructions with a fiber core are more difficult to convert to sea water weight due to their composite construction. Accurately calculating the weight in sea water for these fiber core ropes requires knowledge of the cross sectional areas of the steel and fiber as well as the type of fiber used. Natural fiber cores are usually treated sisal and synthetic fiber cores are polypropylene. As an approximation, the weight in sea water of fiber core ropes of 6 x 7, 6 x 19, and 6 x 37 construction may be obtained by multiplying the weight in air of an IWRC (Independent Wire Rope Core) rope of the same diameter by 0.75.

TABLE 3. 6x7 CLASSIFICATION HAULAGE ROPE

Rope Diameter Inches	Breaking Strength in Tons of 2,000 lb			Approximate Weight in Air Per Foot in lb	
	Monitor Steel IWRC	Monitor Steel Fiber Core	Plow Steel Fiber Core	IWRC	Fiber Core
¼	2.84	2.64	2.3	0.1	0.094
5/16	4.41	4.1	3.56	0.16	0.15
⅜	6.3	5.86	5.1	0.23	0.21
7/16	8.52	7.93	6.9	0.32	0.29
½	11.1	10.3	8.96	0.42	0.38
9/16	14.0	13.0	11.3	0.53	0.48
⅝	17.1	15.9	13.9	0.65	0.59
¾	24.4	22.7	19.8	0.92	0.84
⅞	33.0	30.7	26.7	1.27	1.15
1	42.7	39.7	34.5	1.65	1.5
1⅛	53.5	49.8	43.3	2.09	1.9
1¼	65.6	61.0	53.0	2.57	2.34
1⅜	78.6	73.1	63.6	3.12	2.84
1½	92.7	86.2	75.0	3.72	3.38

From: United States Steel Corporation USS Tiger Brand Wire Rope Handbook

TABLE 4. 6x19 CLASSIFICATION HOISTING ROPE

Rope Diameter Inches	*Breaking Strength in Tons of 2,000 Lb (Bright & AMGAL)							Approximate Weight in Air Per Foot in Lb	
	Monitor AAA Super Tensile			Monitor AA IWRC	Monitor AA Fiber Core	Monitor IWRC	Monitor Fiber Core	IWRC	Fiber Core
	IWRC	Approx Wt/Ft in Lb	Fiber Core						
¼			....	3.40	3.02	2.94	2.74	0.116	0.105
5/16			....	5.27	4.69	4.58	4.26	0.18	0.164
⅜	...		...	7.55	6.71	6.56	6.10	0.26	0.236
7/16	11.2	.35	9.90	10.2	9.09	8.89	8.27	0.35	0.32
½	14.6	.46	12.9	13.3	11.8	11.5	10.7	0.46	0.42
9/16	18.5	.59	16.2	16.8	14.9	14.5	13.5	0.59	0.53
⅝	22.7	.72	20.0	20.6	18.3	17.9	16.7	0.72	0.66
¾	32.3	1.07	28.6	29.4	26.2	25.6	23.8	1.04	0.95
⅞	43.8	1.47	38.6	39.8	35.4	34.6	32.2	1.42	1.29
1	57.5	1.91	50.0	51.7	46.0	44.9	41.8	1.85	1.68
1⅛	71.5	2.42	63.0	65.0	57.9	56.5	52.6	2.34	2.13
1¼	87.9	2.98	77.5	79.9	71.0	69.4	64.6	2.89	2.63
1⅜	106.	3.61	93.0	96.0	85.4	83.5	77.7	3.50	3.18
1½	125.	4.30	111.	114.	101.	98.9	92.0	4.16	3.78
1⅝	145.	5.04	129.	132.	118.	115.	107.	4.88	4.44
1¾	168.	5.85	149.	153.	136.	133.	124.	5.67	5.15
1⅞	191.	6.71	169.	174.	155.	152.	141.	6.50	5.91
2	218.	7.63	192.	198.	176.	172.	160.	7.39	6.72
2⅛	....	....	....	221.	197.	192.	179.	8.35	7.59
2¼	....	....	....	247.	220.	215.	200.	9.36	8.51
2⅜	....	....	....	274.	244.	239.	222.	10.4	9.48
2½	....	....	....	302.	269.	262.	244.	11.6	10.5
2⅝	....	....	....	331.	......	288.	268.	12.8	11.6
2¾	....	....	....	361.	......	314.	292.	14.0	12.7

Galvanizing: For 6x19 classification galvanized wire rope, deduct 10 percent from the listed strength of bright (uncoated) wire rope.
*Acceptance strength is not less than 2½% below the nominal breaking strengths listed.

TABLE 5

USS 18-8 TYPE 304 CORROSION-RESISTING 6x19 AND 6x37 WIRE ROPES

Rope Diameter Inches	Breaking Strength in Lb		Approximate Weight Lb/100 Ft in Air	
	6x19 IWRC	6x37 IWRC	6x19 IWRC	6x37 IWRC
1/4		5,400	.....	11.6
5/16		8,300	.....	18.0
3/8		11,700	.....	26.0
7/16	16,300	15,800	35.6	35.0
1/2	22,800	20,400	45.8	46.0
9/16	28,500	25,500	59.0	59.0
5/8	35,000	31,300	71.5	72.0
3/4	49,600	44,400	105.2	104.0
7/8	66,500	59,700	143.0	142.0
1	85,400	77,300	187.0	185.0
1 1/8	106,400	96,600	240.0	234.0
1 1/4	129,400	118,300	290.0	289.0
1 3/8	153,600	141,400	330.0	350.0
1 1/2	180,500	166,000	420.0	416.0

TABLE 6

GALVANIZED CARBON STEEL AIRCRAFT CABLES

Cable Diam. In.	Zinc-Coated Aircraft Cords				Zinc-Coated Aircraft Strands			Cable Diam. In.
	7x19		7x7					
	Breaking Str. in Lb	Air Weight Lb Per 1,000 Ft	Breaking Str. in Lb	Air Weight Lb Per 1,000 Ft	No. of Wires	Breaking Str. in Lb	Air Weight Lb Per 1,000 Ft	
1/32	.....	.....		.....	7	185	2.5	1/32
3/64		..		..	7	375	5.5	3/64
1/16			480	7.5	19	500	8.5	1/16
5/64	....	....	650	11.0	19	800	14.0	5/64
3/32	.....	.....	920	16.0	19	1,200	20.0	3/32
7/64		.....	1,260	22.0	19	1,600	27.0	7/64
1/8	2,000	29.0	1,700	28.0	19	2,100	35.0	1/8
5/32	2,800	45.0	2,600	43.0	19	3,300	55.0	5/32
3/16	4,200	65.0	3,700	62.0	19	4,700	77.0	3/16
7/32	5,600	86.0	4,800	83.0	19	6,300	102.0	7/32
1/4	7,000	110.0	6,100	106.0	19	8,200	135.0	1/4
9/32	8,000	139.0	7,600	134.0	19	10,300	170.0	9/32
5/16	9,800	173.0	9,200	167.0	19	12,500	210.0	5/16
11/32	12,500	207.0	11,100	201.0	..	......	.....	11/32
3/8	14,400	243.0	13,100	236.0	..	......	.....	3/8

From: United States Steel Corporation, USS Tiger Brand Wire Rope Handbook

TABLE 7. USS 18-8 TYPE 304 AND TYPE 305 (HYCO-SPAN)
CORROSION-RESISTING STEEL AIRCRAFT CABLES

Cable Diam In.	7 x 19 Aircraft Cords: Breaking Str in Lb, Type 304	7 x 19 Aircraft Cords: Breaking Str in Lb, Type 305	7 x 19 Aircraft Cords: Air Weight Lb Per 1,000 Ft	7 x 7 Aircraft Cords: Breaking Str in Lb, Type 304	7 x 7 Aircraft Cords: Breaking Str in Lb, Type 305	7 x 7 Aircraft Cords: Air Weight Lb Per 1,000 Ft	No. Wires	Aircraft Strands: Breaking Str in Lb, Type 304	Aircraft Strands: Breaking Str in Lb, Type 305	Air Weight Lb Per 1,000 Ft	Cable Diam In.
1/32							7	150	130	2.5	1/32
3/64							7	375	300	5.5	3/64
1/16				480	360	7.5	19	500	500	8.5	1/16
5/64				650		11.0	19	800	750	14.0	5/64
3/32				920	700	16.0	19	1,200	1,100	20.0	3/32
7/64				1,260		22.0	19	1,600	1,500	27.0	7/64
1/8	1,760	1,300	29.0	1,700		28.0	19	2,100	2,000	35.0	1/8
5/32	2,400	2,000	45.0	2,400		43.0	19	3,300	3,100	55.0	5/32
3/16	3,700	2,900	65.0	3,700		62.0	19	4,700	4,400	77.0	3/16
7/32	5,000	3,800	86.0	4,800		83.0	19	6,300	6,000	102.0	7/32
1/4	6,400	4,900	110.0	6,100		106.0	19	8,200	7,800	135.0	1/4
9/32	7,800	6,100	139.0	7,600		134.0	19	10,300		170.0	9/32
5/16	9,000	7,600	173.0	9,000		167.0	19	12,500	12,000	210.0	5/16
11/32	10,500	9,300	207.0	10,500		201.0					11/32
3/8	12,000	11,000	243.0	12,000		236.0					3/8

From: United States Steel Corporation USS Tiger Brand Wire Rope Handbook

TABLE 8. 6x24 GALVANIZED MOORING LINE (FIBER CORE)

Rope Diameter Inches	Breaking Strength in Tons of 2,000 Lb		Air Wt/Ft in Lb
	Galvanized MONITOR Steel	Galvanized Plow Steel	
3/8	4.77	4.14	0.194
1/2	8.4	7.3	0.35
9/16	10.6	9.21	0.44
5/8	13.0	11.3	0.54
3/4	18.6	16.2	0.78
13/16	21.8	19.0	0.91
7/8	25.2	21.9	1.06
1	32.8	28.5	1.38
1 1/16	36.9	32.1	1.56
1 1/8	41.2	35.9	1.75
1 3/16	45.9	39.9	1.95
1 1/4	50.7	44.1	2.16
1 3/8	61.0	53.1	2.61
1 7/16	66.5	57.9	2.85
1 1/2	72.3	62.9	3.11
1 5/8	84.5	73.4	3.64
1 11/16	90.9	79.0	3.93
1 3/4	97.5	84.8	4.23
1 13/16	104.0	90.8	4.53
1 7/8	111.0	96.9	4.85
1 15/16	119.0	103.0	5.18
2	126.0	110.0	5.52
2 1/16	134.0	116.0	5.87
2 1/8	142.0	123.0	6.23
2 1/4	158.0	138.0	6.99
2 3/8	176.0	153.0	7.78
2 1/2	194.0	168.0	8.63

From: United States Steel Corporation USS Tiger Brand Wire Rope Handbook

TABLE 9. 6x37 CLASSIFICATION HOISTING ROPE

Rope Diameter Inches	Breaking Strength in Tons of 2,000 Lb			Approximate Weight In Air Per Ft in Lb	
	Monitor AA Steel IWRC	Monitor Steel IWRC	Monitor Steel Fiber Core	Monitor and Monitor AA IWRC	Monitor Steel Fiber Core
¼	3.2	2.78	2.59	0.116	0.105
5/16	4.98	4.33	4.03	0.18	0.164
⅜	7.14	6.2	5.77	0.26	0.236
7/16	9.67	8.41	7.82	0.35	0.32
½	12.6	11.0	10.2	0.46	0.42
9/16	15.9	13.9	12.9	0.59	0.53
⅝	19.6	17.0	15.8	0.72	0.66
¾	27.9	24.3	22.6	1.04	0.95
⅞	37.8	32.9	30.6	1.42	1.29
1	49.1	42.8	39.8	1.85	1.68
1⅛	61.9	53.9	50.1	2.34	2.13
1¼	76.1	66.1	61.5	2.89	2.63
1⅜	91.7	79.7	74.1	3.5	3.18
1½	108.0	94.5	87.9	4.16	3.78
1⅝	127.0	111.0	103.0	4.88	4.44
1¾	146.0	128.0	119.0	5.67	5.15
1⅞	168.0	146.0	136.0	6.5	5.91
2	190.0	165.0	154.0	7.39	6.72
2⅛	214.0	186.0	173.0	8.35	7.59
2¼	239.0	207.0	193.0	9.36	8.51
2⅜	264.0	230.0	214.0	10.4	9.48
2½	292.0	254.0	236.0	11.6	10.5
2⅝	321.0	279.0	260.0	12.8	11.6
2¾	350.0	305.0	284.0	14.0	12.7
2⅞	382.0	333.0	310.0	15.3	13.9
3	414.0	360.0	335.0	16.6	15.1
3⅛	448.0	389.0	362.0	18.0	16.4
3¼	483.0	419.0	390.0	19.5	17.7
3⅜	518.0	451.0	420.0	21.0	19.1
3½	555.0	483.0	449.0	22.7	20.6

Galvanizing: For 6 x 37 classification galvanized wire ropes, deduct 10 percent from the listed breaking strength of bright (uncoated) wire rope.

From: United States Steel Corporation, USS Tiger Brand Wire Rope Handbook

TABLE 10. 6x37 GALVANIZED TOWING HAWSER (FIBER CORE)

Rope Diameter Inches	Breaking Strength in Tons (2,000 Lb)	Approx. in Air Wt/Ft in Lb
1/2	9.18	0.42
9/16	11.6	0.53
5/8	14.2	0.66
3/4	20.3	0.95
13/16	23.8	1.11
7/8	27.5	1.29
1	35.8	1.68
1 1/16	40.3	1.9
1 1/8	45.1	2.13
1 3/16	50.1	2.37
1 1/4	55.4	2.63
1 3/8	66.7	3.18
1 7/16	72.8	3.47
1 1/2	79.1	3.78
1 5/8	92.7	4.44
1 11/16	99.0	4.78
1 3/4	107.0	5.15
1 13/16	114.0	5.52
1 7/8	122.0	5.91
1 15/16	130.0	6.31
2	139.0	6.72
2 1/16	147.0	7.15
2 1/8	156.0	7.59
2 1/4	174.0	8.51
2 5/16	183.0	8.98
2 3/8	193.0	9.48

From: United States Steel Corporation, USS Tiger Brand Wire Rope Handbook

TABLE 11. 3x7, 3x19 and 3x47 TORQUE-BALANCED ROPES WITH AND WITHOUT JACKETS

Bright or AMGAL MONITOR AA Torque-Balanced Rope						Polyurethane Jacketed Rope		Polyethylene Jacketed Rope	
Size Inches	Construction	Weight in Air Lbs/Ft	Weight in Water Lbs/Ft	Breaking Load Pounds	Jacketed Rope	Weight in Air Lbs/Ft	Weight in Water Lbs/Ft	Weight in Air Lbs/Ft	Weight in Water Lbs/Ft
5/32	3x7	.0402	.0349	2,800	.237	.056	.037	.052	.032
3/16	3x19 Seale	.0586	.0509	4,000	.269	.078	.052	.073	.047
1/4	3x19 Seale	.0997	.0867	6,750	.329	.126	.088	.119	.081
5/16	3x19 Seale	.153	.133	10,300	.392	.188	.134	.179	.125
3/8	3x19 Seale	.220	.191	14,800	.456	.265	.192	.253	.181
7/16	3x19 Seale	.304	.264	20,000	.524	.361	.265	.346	.250
1/2	3x19 Seale	.392	.341	25,700	.682	.512	.350	.482	.319
9/16	3x19 Seale	.492	.428	32,500	.746	.631	.437	.596	.402
5/8	3x19 Seale	.602	.523	40,300	.807	.760	.533	.720	.493
3/4	3x19 Seale	.879	.764	57,800	.941	1.08	.774	1.03	.722
7/8	3x19 Seale	1.21	1.05	78,000	1.077	1.46	1.06	1.40	.995
1	3x19 Seale	1.56	1.36	100,600	1.201	1.87	1.36	1.79	1.28
1-1/8	3x19 Seale	1.96	1.70	124,000	1.326	2.32	1.71	2.23	1.62
1/2	3x46 Seale FW	.417	.362	25,700	.688	.539	.374	.508	.343
9/16	3x46 Seale FW	.517	.449	32,500	.747	.657	.462	.621	.426
5/8	3x46 Seale FW	.631	.548	40,300	.809	.790	.562	.749	.521
3/4	3x46 Seale FW	.903	.785	57,800	.936	1.10	.799	1.05	.748
7/8	3x46 Seale FW	1.27	1.10	78,000	1.078	1.52	1.12	1.46	1.05
1	3x46 Seale FW	1.64	1.43	100,600	1.205	1.95	1.44	1.87	1.36
1-1/8	3x46 Seale FW	2.07	1.80	124,000	1.332	2.44	1.82	2.34	1.72
1-1/4	3x46 Seale FW	2.60	2.26	158,000	1.514	3.08	2.29	2.96	2.16
1-3/8	3x46 Seale FW	3.10	2.69	188,000	1.637	3.65	2.72	3.51	2.58
1-1/2	3x46 Seale FW	3.69	3.21	222,000	1.784	4.35	3.24	4.18	3.07
1-5/8	3x46 Seale FW	4.43	3.85	265,000	1.938	5.19	3.88	5.00	3.69
1-3/4	3x46 Seale FW	5.12	4.45	304,000	2.063	5.97	4.48	5.75	4.27

From: USS Tiger Brand Torque-Balanced Wire Rope for Oceanographic and Marine Use, AD USS 55-4999-01, April, 1971

TABLE 12

3x7 TYPE 304 STAINLESS STEEL ROPE		
Size	Minimum Breaking Strength Lbs	Air Weight Lbs/Ft
5/32	2,800	.0406
11/64	3,300	.0491
3/16	3,900	.0578
7/32	5,000	.0745

TABLE 13

3x19 TYPE 304 STAINLESS STEEL ROPE		
Size	Minimum Breaking Strength Lbs	Air Weight Lbs/Ft
11/64	3,500	.0512
3/16	4,000	.0592
7/32	5,400	.0803

TABLE 14

3x19 TENELON STAINLESS STEEL		
Size	Minimum Breaking Strength Lbs	Air Weight Lbs/Ft
3/8	12,700	.221
7/16	17,200	.299
1/2	22,000	.388
9/16	28,000	.487

From: United States Steel Tiger Brand Torque-Balanced Wire Rope for Oceanographic and Marine Use, AD USS 55-4999-01, April 1971

TABLE 15

8x19 CLASSIFICATION HOISTING ROPE (FIBER CORE)

Rope Diameter Inches	Breaking Strength in Tons (2,000 Lb)		Approximate Wt/Ft in Air in Lb
	Monitor Steel	Plow Steel	
¼	2.35	2.04	0.098
5/16	3.65	3.18	0.15
⅜	5.24	4.55	0.22
7/16	7.09	6.17	0.3
½	9.23	8.02	0.39
9/16	11.6	10.1	0.5
⅝	14.3	12.4	0.61
¾	20.5	17.8	0.88
⅞	27.7	24.1	1.2
1	36.0	31.3	1.57
1⅛	45.3	39.4	1.99
1¼	55.7	48.4	2.45
1⅜	67.1	58.3	2.97
1½	79.4	69.1	3.53

From: Unites States Steel Corporation, USS Tiger Brand Wire Rope Handbook

Synthetic Fiber Ropes

Fiber ropes used in cable structures are usually synthetic fiber with a non-rotating construction. The most common fibers used are nylon, polyester (Dacron and Duron), aramid (Kevlar 29 and 49), and polypropylene. The usual constructions are double-braided and single braided or plaited line. Aramid fiber lines are the exception as they are made in a wide variety of constructions. Natural fibers and rotating constructions of lines (e.g. three-strand line) have been omitted from this report since they are either rarely used or are generally unsuitable for use in cable structures. Table 16 presents the average breaking strengths and weights in air for various sizes of double-braided lines manufactured by Samson Ocean Systems, Inc. Table 17 gives the same information for Samson's single braided lines. A conversion factor is given for each type of line to convert weight in air to weight in sea water. This factor can be determined for other fluids as well by using the formula:

$$\text{Conversion Factor, } C = 1 - \frac{\text{specific gravity fluid}}{\text{specific gravity rope}}$$

Example: To determine the weight of 1½" diameter double braided nylon in sea water: 1. Find the rope size and type in Table 16. 2. The weight in air is 60 lbs/100 ft. 3. The conversion factor for this type rope is given in heading box as 0.10. 4. Weight of 1½" diameter double braided nylon in sea water is given by:

$$W_s = 60 \text{ lbs/100 ft} \times 0.10 = .06 \text{ lbs/ft}$$

Table 18 lists the characteristics of the standard aramid constructions available from Philadelphia Resins Corporation, Cortland Cable Company, and Samson Ocean Systems, Inc.

TABLE 16a. SIZE, AVERAGE BREAKING STRENGTH, WEIGHT, AND SPECIFIC GRAVITY OF SAMSON DOUBLE BRAIDED SYNTHETIC ROPE

Brand Name Core-Cover Specific Gravity Sea Water Weight Conversion Factor*	2-in-1 Nylon Nylon-Nylon 1.14 0.10		Stable Braid Polyester-Polyester 1.38 0.25		Power Braid Nylon-Polypropylene 1.01 -0.02 (Buoyant)	
Diameter (in)	Average Breaking Strength (Lbs x 10^{-3})	Weight in Air (Lbs/Ft x 10^{2})	Average Breaking Strength (Lbs x 10^{-3})	Weight in Air (Lbs/Ft x 10^{2})	Average Breaking Strength (Lbs x 10^{-3})	Weight in Air (Lbs/Ft x 10^{2})
1/4	2.3	1.65	2.6	2.3	2.3	1.65
5/16	3.4	2.6	3.9	3.4	3.4	2.6
3/8	4.9	3.7	5.2	4.6	4.4	3.3
7/16	6.6	5.1	7.3	6.4	5.9	4.5
1/2	8.5	6.6	9.4	8.3	7.6	5.9
9/16	11.7	9	12.4	10.9	10.2	8.2
5/8	15.2	12	15.3	13.3	13.0	10.4
3/4	19.1	15	19.1	16.8	16.4	13.2
13/16	23.5	18	---	22.0	20.0	16.2
7/8	28.3	22	27.8	25.5	24.0	19.7
1	33.6	26	36.3	33.6	28.4	23.4
1 1/16	39.3	31	---	37.0	33.0	27.5
1 1/8	45.0	36	44.7	42.5	38.0	32.0
1 1/4	52.0	41	53.0	51.0	43.4	37.0
1 5/16	59.0	47	58.6	57.0	49.0	42.0
1 1/2	74.0	60	69.2	68.0	61.3	53.0
1 5/8	91.0	74	84.0	85.0	75.0	65.0
1 3/4	110	89	101	101	90.0	79.0
2	131	106	118	120	106	94.0
2 1/8	153	124	140	144	123	110
2 1/4	177	144	161	168	142	127
2 1/2	202	165	182	192	162	146
2 5/8	230	188	203	216	183	166
2 3/4	257	212	224	240	204	188
3	285	238	266	288	227	211
3 1/4	322	294	327	360	276	260
3 5/8	384	356	387	432	329	315
4	451	423	427	480	387	374
4 1/4	523	497	506	576	453	411
4 5/8	599	576	584	672	524	514
5	680	662	662	768	594	598

* Multiply weight in air by this factor to obtain weight in sea water in lbs/ft x 10^{2}

From: Samson Marine and Industrial Ropes Catalog, SBRC2-49, Samson Ocean Systems, Inc., Boston, MA

TABLE 16b. SIZE, AVERAGE BREAKING STRENGTH, WEIGHT, AND SPECIFIC GRAVITY OF SAMSON DOUBLE BRAIDED SYNTHETIC ROPE

Brand Name / Core-Cover / Specific Gravity / Sea Water Weight Conversion Factor	NYDAC Nylon-Polyester		Kevlar/Duron Kevlar-Polyester		MFP* 2-in-1 MFP-MFP 0.91 -0.13		2-in-1 Nystron Composite Nylon Polyester 1.24 0.17	
Diameter (in)	Average Breaking Strength (Lbs x 10^{-3})	Weight in Air (Lbs/Ft x 10^{2})	Average Breaking Strength (Lbs x 10^{-3})	Weight in Air (Lbs/Ft x 10^{2})	Average Breaking Strength (Lbs x 10^{-3})	Weight in Air (Lbs/Ft x 10^{2})	Average Breaking Strength (Lbs x 10^{-3})	Weight in Air (Lbs/Ft x 10^{2})
1/4	1.94	1.87					2.50	2.20
5/16	2.60	2.91					3.70	3.10
3/8	3.88	4.21					5.30	4.30
7/16	5.20	5.74					7.10	6.00
1/2	6.70	7.49					10.5	7.60
9/16	9.00	10.2					13.2	9.70
5/8	11.6	13.3					16.0	11.8
3/4	14.5	16.9	32.0	19.0			23.0	17.0
13/16	17.7	20.8	38.0	23.0			27.0	20.1
7/8	21.2	25.2	45.0	28.0			31.5	23.4
1	25.2	30.0	52.0	33.0			40.7	30.4
1 1/16	29.1	35.2	60.0	39.0			45.7	34.5
1 1/8	33.5	40.8	68.0	45.0	27.5	28.7	50.7	38.0
1 1/4	38.2	46.8	77.0	52.0	31.3	33.0	62.8	47.2
1 5/16	43.2	53.3	86.0	59.0	35.2	37.4	74.4	56.9
1 1/2	54.0	67.4	105	75.0	43.8	48.0	88.4	66.7
1 5/8	66.0	83.2	126	92.0	53.2	58.5	100	80.0
1 3/4	79.1	101	148	112	63.5	70.8	121	97.0
2	93.3	130	172	132	74.6	84.2	144	115
2 1/8	109	141	197	156	86.5	99.0	168	135
2 1/4	125	163	224	180	99.2	115	194	157
2 1/2	143	187	252	206	113	132	222	180
2 5/8	160	213	281	235	127	150	263	205
2 3/4	180	241	312	265	141	169	282	231
3	200	270	344	297	156	190	313	259
3 1/4	244	333	412	368	188	234	354	320
3 5/8	290	403	485	443	223	283	422	387
4	337	480	563	527	260	337	496	461
4 1/4			646	619	300	395	575	541
4 5/8			733	718	342	459	658	627
5			825	820	386	526	748	720

* MFP = Multifilament Polypropylene

From: 1. Samson Special Braided Rope Constructions, M12-49, Samson Ocean Systems, Inc., Boston, MA
2. Samson Marine and Industrial Ropes Catalog, SBRC-49, Samson Ocean Systems, Inc., Boston, MA

TABLE 17. SIZE, AVERAGE BREAKING STRENGTH, WEIGHT, AND SPECIFIC GRAVITY OF 12 STRAND SINGLE BRAIDED SYNTHETIC ROPES

Braid Name / Material / Specific Gravity / Sea Water Weight Conversion Factor*	Single Braid Kevlar / Kevlar 29 / 1.44 / 0.28		VLS/Duron / Polyester / 1.38 / 0.25		Samson N-12 / Polypropylene / 0.90 / -0.14		Dura-Plex / Composite Polyester / 1.20 / 0.17	
Diameter (in)	Average Breaking Strength ($Lbs \times 10^{-3}$)	Weight in Air ($Lbs/Ft \times 10^2$)	Average Breaking Strength ($Lbs \times 10^{-3}$)	Weight in Air ($Lbs/Ft \times 10^2$)	Average Breaking Strength ($Lbs \times 10^{-3}$)	Weight in Air ($Lbs/Ft \times 10^2$)	Average Breaking Strength ($Lbs \times 10^{-3}$)	Weight in Air ($Lbs/Ft \times 10^2$)
3/16	3.50	1.0						
1/4	6.50	2.0			1.36	1.04	1.94	1.65
5/16	9.30	3.0			2.17	1.73	2.60	2.43
3/8	12.0	4.0	7.00	4.30	2.95	2.42	3.88	3.49
7/16	14.6	5.0	9.30	6.00	4.10	3.45	5.20	4.76
1/2	22.2	8.0	12.0	7.70	4.83	4.15	6.70	6.21
9/16	27.0	10.0	15.0	10.5	6.28	5.53	9.00	8.45
5/8	36.0	14.0	20.0	13.7	8.40	7.60	11.6	11.0
3/4	42.0	16.0	25.0	17.5	10.4	9.60	14.5	14.0
13/16	50.0	20.0	30.0	21.5	12.6	11.9	17.7	17.3
7/8	60.0	24.0	36.0	26.0	15.0	14.4	21.2	20.9
1	70.0	30.0	42.0	31.0	17.6	17.1	25.0	24.8
1 1/16	80.0	34.0			20.4	20.0	29.1	29.2
1 8/8	92.0	40.0			23.3	23.3	33.5	33.8
1 1/4	104	46.0			26.5	26.7	38.2	38.8
1 5/16	116	52.0			29.8	30.4	43.2	44.2
1 1/2	143	66.0			36.9	38.5	54.0	55.9
1 5/8	173	82.0			44.7	47.5	66.0	69.0
1 3/4	204	99.0			53.2	57.5	79.1	83.5
2	238	118			62.4	68.4	93.3	99.4
2 1/8	275	138			72.2	80.3	109	117
2 1/4	313	160			82.7	93.1	125	135
2 1/2					93.8	107	143	155
2 5/8					105	122	160	177
2 3/4					117	137	180	199
3					130	154	200	224
3 1/4					159	190	244	276
3 5/8					188	230	290	334
4					220	274	337	398

* Multiply weight in air by this factor to obtain weight in lbs/ft

From: 1. Samson Special Braided Rope Constructions, M12-49, Samson Ocean Systems, Inc., Boston, MA
2. Samson Marine and Industrial Ropes Catalog, SBRC-49, Samson Ocean Systems, Inc., Boston, MA

TABLE 18. SIZE, MINIMUM BREAKING STRENGTH AND WEIGHT OF VARIOUS KEVLAR 29 LINE CONSTRUCTIONS

Manufacturer	Manufacturer Designation Construction	DIA (in)	Min. Break Strength (lbs)	Weight in Air (Lbs/Ftx10^3)	Comments
Cortland Cable Company, Inc.	B29 16x15	.085	850	1.8	Single Braided Line
	B29 24x15	.11	1,250	3.1	Single Braided Line
	B29 32x30	.19	3,500	8.0	Single Braided Line
	B29 12x150	.26	6,800	19	Single Braided Line
	B29 16x150	.30	9,000	24	Single Braided Line
	B29 32x150	.42	18,000	50	Single Braided Line
		1/8"	2,000	6.0	Diameter includes nylon braid extruded polyurethane jacket over a parallel fiber type line with a slight twist
		1/4"	8,000	26	
		3/8"	12,000	58	
		1/2"	20,000	90	
		1	60,000	270	
Philadelphia Resins Corporation	PS29-19x7x.23	.23	6,000	18	19 strand with 7 yarns each cable laid line
	PS29-19x7x.33	.33	12,000	36	
	PS29-19x7x.45	.45	17,500	48	
	PS29-19x7x.51	.51	22,000	72	
	PS29-6x19x.58	.58	30,000	95	6 strands with 19 yarns each and independent Kevlar core
	PS29-6x19x.67	.67	36,000	115	
	PS29-6x19x.70	.70	42,000	135	
	PS29-6x19x.85	.85	55,000	186	
	PS29-S-48	.10	1,200	3.5	Single braided line
	PS29-S-75	.13	2,000	6.0	
	PS29-S-72	.21	4,500	12	
	PS29-S-146	.28	7,000	22	
Samson Ocean Systems, Inc.	See Table 17				

Chain

There are two basic types of chain, open link and studlink. Within these two basic types there are various materials, constructions, and heat treatments used to obtain desired strengths. The open link chains most commonly used are proof coil, BBB coil, high test, transport and alloy. Proof coil and BBB coil are made of low carbon steels, high test chain is made of high carbon steel, transport chain is high tensile heat-treated steel, and alloy chain is composed of heat-treated low alloy steel. Open link chain is also available in various corrosion resistant metals but these are rather unusual in application so are not included in this report.

Stud link chain of the various types and grades usually have the same weight and link dimensions although the materials and method of forming links may vary. Once again there are constructions of corrosion resistant steel for which data are not included due to the rarity of use. Table 21 lists the characterisitcs of the types of chain which will usually be found in surplus or Navy stocks (Di-lok was a Navy developed design). Table 22 lists the same information for grades of stud link chains established by the American Bureau of Shipping. Table 23 lists characteristics of chain designated as Oil Rig Quality by the American Petroleum Institute which is used on most drill ships and platforms.

Table 19 gives values of constants which can be used to approximate the weight and strength of chain for a known chain size (chain size for this formula is specified as the diameter of the bar forming the link). More often, the designer will select a chain for its strength and weight and

thus determines the "trade size" of chain required. Actual bar diameter is somewhat greater than trade size. Tables 20 and 21 are included for this purpose and for the larger chain sizes not covered by the formula in Table 19. Weights given are in air and must be multiplied by 0.87 to obtain sea water weight.

TABLE 19

WEIGHT AND STRENGTH OF CHAIN

LINK	GRADE	PARAMETER	AIR WEIGHT lb/ft	PROOF STRENGTH lb	ULTIMATE STRENGTH lb
Stud[1]	Forged	Multiplier	10.51	84,090	128,500
		Exponent	1.929	1.928	1.916
Open[2]	Proof Coil	Multiplier	10.22	37,670	65,920
		Exponent	1.918	1.851	1.851
Open[2]	Heat Treated	Multiplier	10.39	61,000	106,800
		Exponent	1.879	1.767	1.767
Open[2]	High Tensile	Multiplier	10.19	89,650	156,900
		Exponent	1.860	1.819	1.819
Open[2]	Alloy Steel[3]	Multiplier	9.651	98,800	172,900
		Exponent	1.915	1.883	1.883

Air Weight (Lb/ft)
Proof Strength (Lb)
Ultimate Strength (Lb)

= Mult. *D ** Exp.,

where D = diameter of bar forming

$0.25 < D < 1.00$

1 Baldt Anchor, Chain and Forge Div., The Boston Metals Co.

2 Reference 7, page 35

3 Suitable for overhead hoisting

From: A Short Compendium of the Physical Properties of Mooring Line Components, CR80.0020, Civil Engineering Laboratory, Naval Construction Battalion Center, May 1981

TABLE 20

SIZE, WIDTH, WEIGHT, AND BREAKING STRENGTH OF OPEN LINK CHAINS*

Trade Size (in)	Bar Diameter (in)	Proof-Coil Outside Link Width (in)	Proof-Coil Weight in Air (Lbs/Ft)	Proof-Coil Working Load Limit (Lbs)	BBB-Coil Outside Link Width (in)	BBB-Coil Weight in Air (Lbs/Ft)	BBB-Coil Working Load Limit (Lbs)	High-Test Transport Quality Outside Link Width (in)	High-Test Transport Quality Weight in Air (Lbs/Ft)	High-Test Transport Quality High-Test Working Load Limit (Lbs)	High-Test Transport Quality Transport Working Load Limit (Lbs)	Alloy Outside Link Width (in)	Alloy Weight in Air (Lbs/Ft)	Alloy Working Load Limit (Lbs)
3/16	7/32	0.84	0.42	700	0.81	0.46	800					0.54	0.42	2,000
1/4	9/32	1.06	0.76	1,175	0.99	0.81	1,325	0.95	0.80	2,500	4,200	0.95	0.73	3,250
5/16	11/32	1.18	1.15	1,750	1.19	1.20	1,950	1.17	1.23	4,000	6,300	1.13	0.92	4,250
3/8	13/32	1.43	1.66	2,450	1.43	1.73	2,750	1.37	1.75	5,100	8,800	1.33	1.63	6,600
7/16	15/32	1.68	2.25	3,250	1.62	2.31	3,625	1.59	2.35	6,600	11,700			
1/2	17/32	1.87	2.86	4,250	1.81	2.96	4,750	1.81	3.00	8,200	15,000	1.78	2.70	11,250
9/16	19/32	2.06	3.55	5,250	1.97	3.66	5,875							
5/8	21/32	2.31	4.25	6,375	2.18	4.47	7,250	2.21	4.50	11,500	22,900	2.22	4.22	16,500
3/4	25/32	2.68	6.05	9,125	2.56	6.40	10,250	2.62	6.55	16,200	32,400	2.53	5.90	23,000
7/8	28/32	3.18	8.11	10,750	3.06	8.50	12,000					2.84	7.30	28,750
1	1 1/32	3.56	10.5	12,400	3.43	10.9	15,500					3.25	9.65	38,750
1 8/8	1 5/32	4.06	13.2	15,600	3.93	13.6	19,500							
1 1/4	1 9/32	4.43	16.2	19,200	4.31	16.6	24,000					4.15	15.25	57,500

* These are typical values to be used in analysis. Final design should use values obtained from the chain manufacturer as sizes, weights, and working load limits vary from one manufacturer to the next.

After: Handbook of Ocean and Underwater Engineering; Myers, Holms, and McAllister (ed); North American Rockwell Corporation, 1969, published by McGraw-Hill.

Table 21

Size, Weight (in-air), and Strength of Stud Link Chains Common in Navy Stocks

Chain size, In.	Link width B, in.	Weight per 15-fathom shot (approx), lb	Wrought iron: Proof test, lb	Wrought iron: Break test, lb	Hi-strength: Proof test, lb	Hi-strength: Break test, lb	Di-Lok: Proof test, lb	Di-Lok: Break test, lb
3/4	2 5/8	505	22,680	33,880	34,680	48,550	48,000	75,000
13/16	2 7/8	600	26,600	39,872	40,430	56,600	56,000	86,500
7/8	3 1/8	688	30,800	46,200	46,630	65,280	64,000	98,000
15/16	3 5/16	795	35,392	53,088	53,280	74,590	74,000	113,500
1	3 9/16	900	40,320	60,480	60,360	84,500	84,000	129,000
1 1/16	3 3/4	1,020	45,472	68,096	67,850	94,990	95,000	145,000
1 1/8	4	1,140	50,960	76,440	75,770	106,080	106,000	161,000
1 3/16	4 1/4	1,275	56,840	85,120	84,120	117,770	118,000	179,500
1 1/4	4 1/2	1,415	63,000	94,360	92,910	130,070	130,000	198,000
1 5/16	4 3/4	1,560	69,440	104,160	102,090	142,930	143,500	216,500
1 3/8	4 15/16	1,705	76,120	114,240	111,660	156,330	157,000	235,000
1 7/16	5 3/16	1,865	83,160	124,600	121,720	170,430	171,000	257,500
1 1/2	5 3/8	2,035	90,720	131,488	132,190	185,060	185,000	280,000
1 9/16	5 5/8	2,195	98,336	137,536	143,050	200,270	200,500	302,500
1 5/8	5 7/8	2,345	106,400	148,960	154,310	216,030	216,000	325,000
1 11/16	6 1/16	2,530	114,800	160,720	165,960	232,360	232,500	352,500
1 3/4	6 5/16	2,720	123,480	172,760	178,000	249,210	249,000	380,000
1 13/16	6 1/2	2,925	132,440	185,360	190,430	266,620	267,000	406,000
1 7/8	6 3/4	3,125	141,680	198,240	203,250	284,540	285,000	432,000
1 15/16	7	3,335	151,200	211,680	216,430	303,000	303,500	460,000
2	7 3/16	3,525	161,280	225,792	230,000	322,000	322,000	488,000
2 1/16	7 7/16	3,750	171,360	239,904	243,930	341,510	342,000	518,000
2 1/8	7 5/8	3,975	182,000	254,800	258,240	361,530	362,000	548,000
2 3/16	7 7/8	4,215	192,920	269,920	272,910	382,060	382,500	579,100
2 1/4	8 1/8	4,460	204,120	285,600	287,930	403,100	403,000	610,000
2 5/16	8 5/16	4,710	215,600	301,840	303,320	424,630	425,000	642,500
2 3/8	8 9/16	4,960	227,360	318,304	319,050	446,660	447,000	675,000
2 7/16	8 3/4	5,210	239,456	335,160	335,130	469,180	469,500	709,500
2 1/2	9	5,528	252,000	352,800	351,560	492,190	492,000	744,000
2 9/16	9 1/4	5,810	261,408	365,960	368,340	515,670	516,000	778,500
2 5/8	9 7/16	6,105	270,816	379,120	385,140	539,620	540,000	813,000
2 11/16	9 11/16	6,410	280,224	392,280	402,890	564,040	565,000	849,000
2 3/4	9 7/8	6,725	289,632	405,440	420,660	588,930	590,000	885,000
2 13/16	10 1/8	7,040	298,816	418,320	438,760	614,260	615,000	925,000
2 7/8	10 3/8	7,365	308,224	431,480	457,190	640,070	640,000	965,000
2 15/16	10 9/16	7,696	317,408	444,360	475,940	666,310	666,500	1,005,000
3	10 13/16	8,035	326,592	457,184	495,000	693,000	693,000	1,045,000
3 1/16	11	8,379	335,552	469,728	514,380	720,130	720,500	1,086,500
3 1/8	11 1/4	8,736	344,400	482,160	531,060	747,680	748,000	1,128,000
3 3/16	11 1/2	9,093	353,248	494,480	554,050	775,670	776,050	1,169,000
3 1/4	11 11/16	9,460	361,984	506,688	574,340	804,070	804,100	1,210,000
3 5/16	11 15/16	9,828	370,496	518,560	594,920	832,890	833,150	1,253,000
3 3/8	12 1/8	10,210	378,840	530,320	615,800	862,130	862,200	1,296,000
3 7/16	12 3/8	10,599	386,960	541,632	636,970	891,770	892,100	1,339,550
3 1/2	12 5/8	10,998	395,136	553,056	658,440	921,810	922,000	1,383,100
3 5/8	13 1/16	11,607	410,253	570,688	702,750	984,600	1,021,000	1,566,000
3 3/4	13 1/2	12,626	425,370	588,320	747,070	1,045,900	1,120,000	1,750,000
3 7/8	14	13,340	442,300	618,600	793,000	1,100,200	1,205,000	1,863,400
4	14 3/8	14,100	455,000	636,000	840,000	1,176,000	1,298,000	1,996,500
4 1/8	14 7/8	15,000	461,550	646,000	863,900	1,209,400	1,347,400	2,062,500
4 1/4	15 5/16	15,900	468,100	655,000	888,000	1,243,200	1,393,700	2,134,000
4 3/8	15 3/4	16,860	492,200	688,400	987,000	1,381,700	1,569,700	2,398,000
4 1/2	16 3/16	17,840	502,700	703,100	1,037,800	1,452,900	1,672,000	2,508,000
4 5/8	16 5/8	18,840	510,300	713,700	1,089,600	1,525,400	1,775,000	2,675,000
4 3/4	17 1/8	19,840	518,500	725,300	1,142,000	1,599,000	1,870,000	2,806,000

From: Handbook of Ocean and Underwater Engineering; Myers, Holms, and McAllister (ed); North American Rockwell Corporation, 1969, published by McGraw-Hill. Used with the permission of Mc-Graw-Hill Company.

Table 22

AMERICAN BUREAU OF SHIPPING

Stud Link Anchor Chain Proof and Break Tests

Chain Diameter in	Normal Strength Grade 1		High Strength Grade 2		Extra High Strength Grade 3		Minimum Wt Pounds Per 15 Fathoms lbs *
	Proof Load lbs	Breaking Load lbs.	Proof Load lbs.	Breaking Load lbs.	Proof Load lbs.	Breaking Load lbs	
1/2	10685	15275	15275	21390	21390	30555	225
9/16	13505	19285	19285	26995	26995	38575	290
5/8	16620	23745	23745	33220	33220	47465	365
11/16	20050	28625	28625	40095	40095	57275	405
3/4	23790	33980	33980	47580	47580	67960	480
13/16	27845	39760	39760	55655	55665	79520	570
7/8	32165	45965	45965	64355	64355	91840	655
15/16	36825	52620	52620	73650	73650	105210	755
	41775	59695	59695	83550	83550	119390	855
1 1/16	46985	67155	67155	94055	94055	134850	970
1 1/8	52640	75040	75040	105050	105050	150080	1085
1 3/16	58350	83440	83440	116700	116700	166770	1215
1 1/4	64510	92180	92180	129020	129020	184240	1345
1 5/16	70900	101250	101250	141800	141800	202500	1485
1 3/8	77510	110810	110810	155200	155200	221600	1625
1 7/16	84450	120740	120740	169000	169000	241470	1775
1 1/2	91730	131040	131040	183450	183450	262080	1935
1 9/16	99230	141800	141800	198500	198500	283600	2090
1 5/8	107940	152880	152880	213920	213920	305650	2235
1 11/16	115020	166660	166660	229090	229090	326700	2410
1 3/4	123300	176180	176180	246620	246620	352240	2590
1 13/16	131820	188380	188380	263600	263600	376600	2785
1 7/8	140670	200900	200900	281300	281300	401900	2975
1 15/16	149500	213600	213600	299300	299300	426900	3175
2	159040	227100	227100	318100	318100	454400	3355
2 1/16	168580	240800	240800	337100	337100	481600	3570
2 1/8	178400	254800	254800	356700	356700	509600	3785
2 3/16	188400	269100	269100	376900	376900	538300	4015
2 1/4	198600	283900	283900	396400	396400	569700	4245
2 5/16	209200	298900	298900	418400	418400	597700	4485
2 3/8	212000	314300	314300	439900	439900	628400	4725
2 7/16	230900	330000	330000	461900	461900	659800	4960
2 1/2	242100	346000	346000	484300	484300	691800	5265
2 9/16	253500	363300	363300	507200	507200	725600	5535
2 5/8	265200	378900	378900	530400	530400	757800	5815
2 11/16	277100	395800	395800	554200	554200	791600	6105
2 3/4	289200	413100	413100	578400	578400	826200	6405
2 13/16	301300	430700	430700	603000	603000	861400	6705
2 7/8	313900	448600	448600	628000	628000	897000	7015
2 15/16	326600	466700	466700	653500	653500	933500	7330
3	339600	485200	485200	679200	679200	970300	7650
3 1/16	352700	503900	503900	705400	705400	1007700	7980
3 1/8	365900	522900	522900	732100	732100	1045800	8320
3 3/16	379500	542200	542200	759000	759000	1084300	8660
3 1/4	393100	561700	561700	786500	786500	1123500	9010
3 5/16	407100	581500	581500	814100	814100	1163100	9360
3 3/8	421000	601700	601700	842500	842500	1203500	9725
3 7/16	435300	622000	622000	870800	870800	1244000	10095
3 1/2	449700	642700	642700	899900	899900	1285400	10475
3 9/16	464500	663500	663500	928800	928800	1326900	10860
3 5/8	479200	684500	684500	958400	958400	1369200	11250
3 3/4	509300	727600	727600	1018500	1018500	1455000	12025
3 7/8	540000	771500	771500	1080000	1080000	1542800	12850
3 15/16	555600	793700	793700	1111100	1111100	1587400	13275
4	571300	816100	816100	1142700	1142700	1632400	13700
4 1/8	603300	861800	861800	1206600	1206600	1723700	14560
4 1/4	635800	908300	908300	1271800	1271800	1816800	15350
4 3/8	669000	955700	955700	1338000	1338000	1911300	16200
4 1/2	702700	1003700	1003700	1405300	1405300	2007500	17100
4 5/8	736700	1052600	1052600	1473600	1473600	2105200	18000
4 3/4	771500	1102100	1102100	1542900	1542900	2204200	18900
4 13/16	789100	1127300	1127300	1578200	1578200	2254600	19400
4 7/8	806700	1152500	1152500	1613400	1613400	2304900	19900
5	842300	1203300	1203300	1684600	1684600	2406600	20900
5 1/8	878300	1254700	1254700	1756600	1756600	2509400	22000
5 3/16	896400	1280600	1280600	1792900	1792900	2561300	22500
5 7/16	970000	1385700	1385700	1940000	1940000	2771400	24500
5 5/8	1026000	1465800	1465800	2052100	2052100	2931500	26100
5 13/16	1082800	1546800	1546800	2165500	2165500	3093600	27600
6	1140100	1628700	1628700	2280200	2280200	3257400	29100

From: Vicinay Anchors and Chain Catalog, Vicinay International Company, Inc., Houston, Texas

* weight in-air

Table 23

Size, Strength, and Weight of Oil Rig Quality

Stud Link Chain

Diameter	Proof load	Breaking load	Approx. weight*	
			15 Fathoms	1000 Feet
Inches	lbs	lbs	lbs	lbs
2	324000	489000	3528	39200
2 1/16	344000 •	518000 •	3748	41644
2 1/8	364000	548000	3971	44122
2 3/16	384000 •	579000 •	4218	46866
2 1/4	405000	611000	4454	49488
2 5/16	427000 •	643000 •	4749	52766
2 3/8	449000	676000	5016	55733
2 7/16	471000 •	710000 •	5285	58722
2 1/2	494000	744000	5580	62000
2 9/16	517000 •	779000 •	5878	65311
2 5/8	541000	815000	6176	68622
2 11/16	565000 •	852000 •	6471	71900
2 3/4	590000	889000	6782	75355
2 13/16	615000 •	927000 •	7111	79011
2 7/8	640000	965000	7435	82611
2 15/16	660000 •	1004000 •	7777	86411
3	693000	1044000	8116	90177
3 1/16	719000 •	1084000 •	8460	94000
3 1/8	747000	1125000	8815	97944
3 3/16	774000 •	1167000 •	9188	102088
3 1/4	802000	1209000	9543	106033
3 5/16	830000 •	1252000 •	9929	110322
3 3/8	859000	1295000	10314	114600
3 7/16	888000 •	1338000 •	10700	118888
3 1/2	918000	1383000	11102	123355
3 9/16	947000 •	1428000 •	11488	127644
3 5/8	977000	1473000	11878	131978
3 3/4	1039000	1566000	12661	140678
3 7/8	1101000 •	1660000 •	13446	149400
3 15/16	1133000 •	1708000 •	14097	156633
4	1165000	1756000	14324	159156
4 1/8	1231000 •	1855000 •	15272	169689
4 1/4	1297000	1955000	16405	182277
4 3/8	1365000 •	2057000 •	17441	193788
4 1/2	1433000	2160000	18477	205300
4 5/8	1503000 •	2265000 •	19260	214000
4 3/4	1574000	2372000	20263	225144
4 7/8	1645000 •	2479000 •	21642	240465
5	1718000	2589000	22766	252955
5 1/8	1791000 •	2700000 •	23902	265577
5 1/4	1865000	2811000	25100	278888
5 3/8	1941000 •	2925000 •	26371	293011
5 1/2	2016000	3038000	27500	305555
5 5/8	2093000 •	3154000 •	28700	318889
5 3/4	2170000	3270000	30054	333933
6	2325000	3505000	32567	361855

• Infrequent

*in-air

From: Ramnäs Anchor Chains, Reprint from 34th (1980-1981) Composite Catalog, Bulten - Kanthal AB, Ramnäs, Sweden

Electromechanical Cables

EM cables come in a wide variety of constructions. Table 24 gives a formula for calculating approximate cable weights and strengths based on the stock off-the-shelf cables available from the Rochester Corporation. Tables 25-27 are excerpts from the Rochester Catalog which gives the characteristics of the EM cables upon which Table 24 is based. Examples of Rochester custom designed EM cables are given in Table 28. Usually the designer will have a cable design and characteristics to use in the programs. The above tables will help if no cable design data are available and stock cable can be used.

If the cable construction is unusual the weight in air may be determined by calculating the weight of each component by:

$$\text{lbs in air/1000 ft} = A_{cm} \times 3.4 \times 10^{-4} \times \text{specific gravity}$$

A_{cm} = cross sectional area in circular mills of component

and summing the total. The weight in sea water would be performed similarly using:

$$\text{lbs in sea water/1000 ft} = A_{cm} \times 3.4 \times 10^{-4} \left(1 - \frac{1.03}{\text{specific gravity}}\right)$$

The Rochester catalog suggests the following relations for their cables.

1. Jacketed Cable

   lbs in sea water/1000 ft = lbs in air/1000 ft - 349 D^2

2. Armoured Cable

   lbs in sea water/1000 ft = lbs in air/1000 ft - 315 D^2

   with D = diameter of cable in inches

Table 29 lists the specific gravities and application of the materials most commonly used in cable construction.

Table 24

WEIGHT AND STRENGTH OF UNJACKETED STEEL DOUBLE ARMOR ELECTROMECHANICAL CABLES*

	AIR WEIGHT lb/ft	SEAWATER WEIGHT lb/ft	BREAKING STRENGTH lb
Multiplier, M	1.424	1.092	62,940
Exponent, E	1.881	1.844	1.776

Air Weight, lb/ft

Seawater Weight, lb/ft = M * D ** E,

Breaking Strength, lb

Where D is the outside diameter in inches:

$0.1 < D < 1.0$

* Based on 78 stock cables from Reference 6.

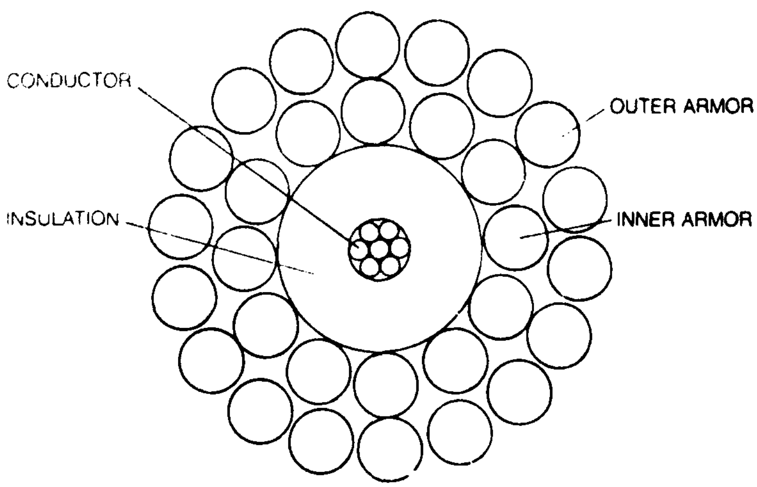
The formulas are accurate within 5% for typical cables. Unusual selection of core conductors and/or number of armor wires strongly affects accuracy.

From: A Short Compendium of the Physical Properties of Mooring Line Components, CR80.0020, Civil Engineering Laboratory, Naval Construction Battalion Center, May 1981

TABLE 25. OCEANOGRAPHIC ELECTRO-MECHANICAL CABLES SINGLE CONDUCTOR-MECHANICAL CHARACTERISTICS

Type	Stock #	Armor OD – Inches	Inner Armor No. In.	Outer Armor No. Inches	Jacket Thk/Mat.–In.	Break Str. Lbs	Wt. Air (Lbs/1000')	Wt. Sea Wtr (Lbs/1000')	Min. Sheave Diam.–In.	Calc. Armor Ratio
1 H-100	10100	.102	12/.014	18/.014	–	1000	19	15	6	2.2
1 H 100 J	10162	"	"	"	.030 PU	"	25	16	"	"
1 H 122	10112	"	"	"		1100	21.5	17	5	1.9
1 H 142	10142	"	"	"	.015 PE	"	23.9	17.5	"	1.7
1 H 172	10172	"	"	"	.030 Hy	"	28.9	19.6	"	1.9
1 H-150	10150	"	18/.012	14/.012 8 Fillers	.019 PE	1000	20.0	12.9	"	1.17
1 H 125	10124	124	12/017	18/017	-	1500	27	22	7	2.2
1 H 209 J	10209	.169	18/018	24/018	.020 PE	2370	54	39	"	1.7
1 H 197 J	10197	133	18/.018	none	.032 PE	950	33	19	7	N/A
1 H 0	10187	.185	18/.018	18/.0245	..	3000	55	44.5	10	2.5
1 H 186	10186	.184	"	18/.0245	–	2900	57	46	10	2.6
1 H 204	10204	.200	12/030	23/.022	–	3700	69	56	12	1.6
1 H 254 J	10254	"	"	"	.025 PE	"	76	"	"	"
1 H 219	10219	.220	15/.0245	15/035	–	4500	90	74	14	3.0
1 H 220 PP	10220	"	"	"	–	"	92	76	"	"
1 H 250 PP	10249	.254	18/.0245	18/.035	–	5900	106	86	"	2.5
1 H 250 R	10250	"	"	"	–	"	108	88	"	"
1 H 250 PE	10251	"	"	"	–	"	106	86	"	"
1 H 255	10255	"	12/.035	18/.035	–	6300	115	95	"	2.1
1 H 258	10258	.252	"	"	–	"	113	93	"	"
1 H 335 J	10335	.261	18/.028	24/.028	.037 PE	5200	123	84	11	1.4
1 H 293	10293	.294	18/.029	18/.040	–	7200	153	126	16	2.6
1 H 2 J	10385	313	12/.0435	18/.0435	036 PE	10000	198	146	17	2.0
1 H 3	10375	375	12/.051	18/.051	-	13000	243	199	20	1.9

NOTE All values are nominal



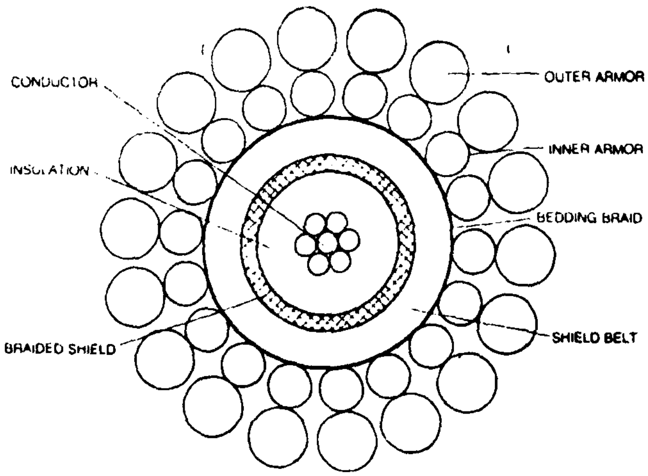
Typical Construction of Single Conductor Armored Cable

From: Electromechanical Oceanographic Cables and Electrical Underwater Connectors, The Rochester Corporation, Culpepper, Virginia, 1975

TABLE 26. OCEANOGRAPHIC COAXIALS-MECHANICAL CHARACTERISTICS

Type	Stock #	Armor OD Inches	Core Dia. – Inches	Inner Armor No./In	Outer Armor No./In.	Jacket Thk./Mt. – Inches	Calc. Armor Ratio	Weight Lbs./1000 Air	Weight Lbs./1000 Sea Water	Break Str. Lbs.	Min. Sheave Dia.(In.)
2 H-160	20160	.160	.078	12/.024	23/.017	-	1.6	45	37	2300	9
2-H-0	20188	.185	[illegible]	18/.018	18/.0245	–	2.3	62	50	2900	10
2 H 251	20251	.251	.147	22/.022	21/.030	–	2.3	104	84	4900	12
2 H-252	20252	.252	.133	18/.0245	18/.035	–	2.3	107	87	5500	14
2 H 255	20255	.255	.147	18/.027	24/.027	–	1.4	107	86	6000	11
2 H 288 J	20288	.244	.190	23/.027	None	.025 PE	–	82	53	3000	11
2 H 1	20291	.290	.157	18/.028	18/.0385	–	2.4	145	119	7200	16
2 H 58U	20294	.294	.143	12/.0435	23/.032	-	1.5	146	119	7800	17
2 H 300	20300	.304	.158	18/.032	24/.032	-	1.6	145	116	7400	13
2 H 2	20327	.321	.170	18/.032	18/.0435	–	2.5	176	143	9200	"
2 H 349	20349	.349	.202	18/.037	24/.037	–	1.6	225	187	9500	15
2 H-371	20371	.294	.158	15/.037	24/.031	.038" Ht.	1.5	174	126	10000	15
2 H-59U	20377	.377	.226	18/.0435	30/.032	–	1.4	212	167	10000	"
2 H-4	20431	.434	.232	18/.0435	18/.0575	–	2.5	320	262	16000	23
T-Mk-6	20470	.295	.161	18/.028	18/.0385	.058 Lead .030 Ny	2.4	497	420	6400	16
2 H-477	20477	.477	.285	18/.054*	30/.042*	–	1.25	354	282	17000	22
2 H-528	20528	.528	.304	18/.056	24/.056	–	1.5	434	346	20000	22
20590	20590	.592	.368	24/.049	24/.063	–	2.0	562	452	24000	25
2 H-213U	20609	.609	.404	22/.059	36/.0435	–	1.06	514	384	26000	24
2 H-679	20679	.669	.417	24./056	24/.070	–	2.0	680	539	32000	28
2 H-680	20683	.680	.450	22/.065	36/.050	–	1.04	659	514	31000	26
2 H-696	20696	.698	.350	24/.047	24/.059	–	1.05	824	671	45000	27
2 H-726	20726	.726	.470	21/.074	36/.054	–	1.07	764	398	40000	30
Triple Armor					27/.068						
#2 Coax	21148	1.148	.840	36/.070	36/.084	–	1.7	1925	1510	70000	34
Triax	30517	.517	.357	36/.030	–	.050" PE	–	232	139	5500	12
Non Magnetic Magnetometer Cables – Beryllium Copper Armor											
2 H 161	20161	.157	.089	18/.017	23/.017	-	1.9	46	38	1200	7
RG 58 U	20372	.302	.188	24/.025	24/.032	.035 PE	"	168	120	4000	13

*Stainless Steel
NOTE All values are nominal



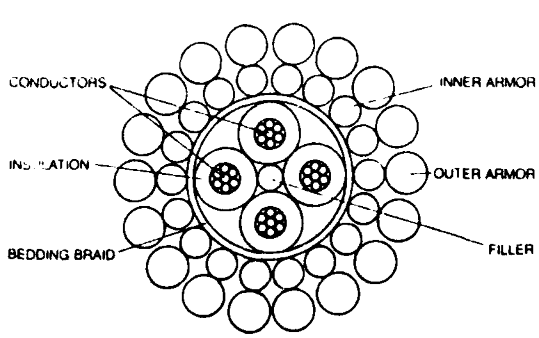
Typical Construction of Armored Coaxial

From: Electromechanical Oceanographic Cables and Electrical Underwater Connectors, The Rochester Corporation, Culpepper, Virginia, 1975

TABLE 27. OCEANOGRAPHIC ELECTRO-MECHANICAL CABLES
MULTI-CONDUCTOR MECHANICAL CHARACTERISTICS

Type	Stock #	Armor OD In.	Core Dia. In.	Inner Armor No. In.	Outer Armor No. In.	No. Conductors	AWG	Calc. Armor Ratio	Break Str. Lbs.	Wt. Air Lbs/1000'	Wt. Sea Wtr Lbs/1000'	Min. Sheave Diam. In.
3 H-0 PP	30182	.183	.098	18/.018	18/.0245	3	24	2.3	2900	57	46	10
3 H-187	30187	.191	.114	22/.017	22/.022	3	24	"	2900	57	47	9
3 H-230 J	30230	.166	.122	18/.022	None	3	22	N/A	1500	45	27	9
3 H-250	30250	.254	.134	18/.0245	18/.035	3	22	2.5	5500	109	88	14
3 H 1	30295	.295	.182	24/.0245	24/.032	3	20	1.9	6900	133	106	13
3-H 2	30322	.321	.170	18/.032	18/.0435	3	20	2.5	9200	170	137	18
3 H 3	30374	.371	.234	24/.030	24/.0385	3	18	2.0	10000	202	158	16
3 H 420	30420	.419	.262	24/.035	24/.0435	3	14	1.9	12500	271	216	18
3 H 460	30460	.460	278	18/.051	30/.040	3	16	1.09	19600	316	250	20
3 H 526	30526	.526	.320	18/.058	30/.045	3	16	1.3	26800	404	318	23
4 H 0	40185	.183	098	18/.018	18/.0245	4	24	2.6	2900	57	46	10
4 H 218	40218	.220	.116	18/.022	18/.030	4	24	2.7	4400	86	71	12
4 H-225	40225	.220	.116	18/.022	18/.030	4	24	2.5	4400	82	67	12
4-H 250	40250	.254	.134	18/.0245	18/.035	4	23	"	5500	107	85	14
4 H 292	40292	.282	.149	18/.028	18/.0385	4	22	2.6	7200	142	115	16
4 H 350	40349	.349	.201	18/.037	24/.037	4	19	1.6	9700	194	156	15
BRA-8	40352	.351	.201	18/.0377*	24/.0377*	4	19	"	10400	208	169	"
4 H 3	40375	.375	.199	18/.037	18/.051	4	22	2.6	11800	219	175	20
4 H 412	40412	.409	256	24/.035	24/.0435	4	18	1.8	11500	255	203	17
7 H 2	70321	.323	.172	18/.032	18/.0435	7	22	2.4	9200	175	145	18
7 H 2	70325	.323	.172	18/.032	18/.0435	7	22	2.3	9200	174	141	18
7-H-3	70374	.375	.199	18/.037	18/.051	7	20	2.6	11800	243	196	20
7 H 420	70420	.420	.262	24/.035	24/.0435	7	18	1.9	12500	278	222	18
7 H 422 PP	70422	.421	220	18/.0435	18/.0575	7	20	2.5	16000	305	249	23
7 H 4 PP	70463	.464	289	24/.0385	24/.049	7	20	2.0	16000	322	253	20
8 H 575	80575	.589	389	22/.0575	36/.0435	8	16	1.2	23000	499	380	23
10 H 465	90465	463	289	24/.0385	24/.049	10	22	2.0	16000	312	244	20
12 H 675	90675	671	417	24/.0575	24/.070	12	18	1.8	30000	667	521	28
[illegible]	[illegible]	1.023	661	21/.104	35/.077	37	19	1.13	72000	1508	1179	42

* [illegible]ess Ste[illegible]
NOTE: All values are nominal



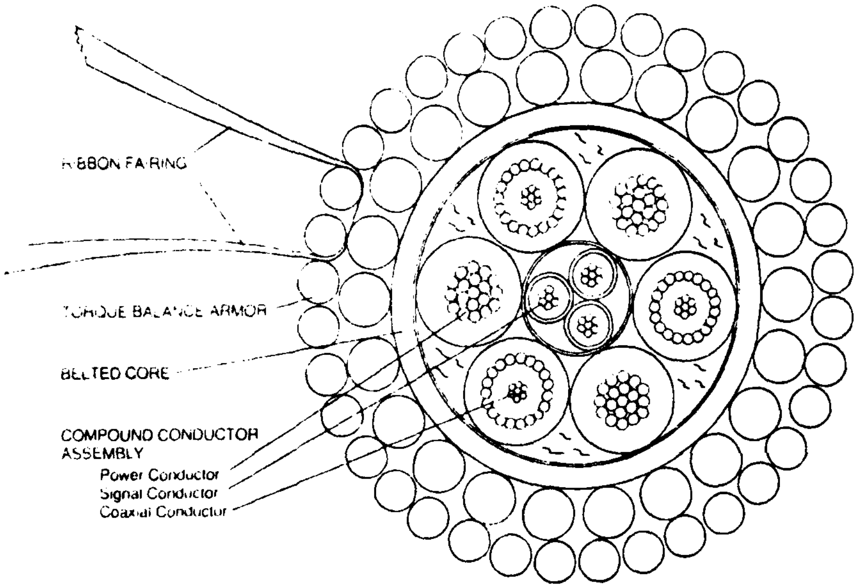
Typical Construction of a Multiconductor Armored Cable

From: Electromechanical Oceanographic Cables and Electrical Underwater Connectors, The Rochester Corporation, Culpepper, Virginia, 1975

TABLE 28a. CUSTOM DESIGNED OCEANOGRAPHIC CABLES
MECHANICAL CHARACTERISTICS

Stock #	Armor OD In.	Core Dia. Inches	Inner Armor No./In.	Outer Armor No./In.	Armor Jacket Thk/Mtl – Inches	Calc. Armor Ratio	Break Str. Lbs.	Wt. Air Lbs./1000 ft.	Wt. Sea Wtr. Lbs./1000 ft.	Min. Sheave Diam. In.
30300	.300	.186	24/.025	24/.032		2.0	4700	169	141	13
			Beryllium Copper							
50519	.523	.328	24/.0435	24/.054	–	1.9	19000	397	312	22
60580	240	.162	15/.039	–	.030 Nyl	–	9200	600	477	24
			(3 armored coaxes w/lead fillers)							
80302	.302	.189	24/.0245	24/.032	-	1.9	6800	143	114	13
80464	464	289	24/.0385	24/.049	–	2.0	16000	347	279	20
90347	.347	2.03	18/.037	24/.037	–	1.7	9700	196	159	15
90463	463	.288	24/.0385	24/.049	–	2.0	16000	350	283	20
90552	454	.390	36/.032	–	.049 PU	N.A.	5000	276	169	13
90645	.645	.432	24/.0575	35/.049	–	1.17	26800	566	435	23
90653	.653	.440	24/.0575	35/.049	-	1.13	26,400	573	437	23
90667	.667	.489	36/.041	36/.048	–	1.5	21,600	600	460	19
90680	.675	445	22/.065	36/.050	–	1.05	33000	655	511	26
			Stainless Steel							
90688	.688	.425	24/.0575	24/.074	–	1.9	35000	782	633	30
90786	.786	.450	18/.084	24/.084	–	1.7	45000	1034	840	34
90788	.788	.578	22/.077	36/.057	–	1.01	40000	902	707	31
90812	.812	.594	35/.051	35/.0575	–	1.7	33000	1015	809	20
90815	.815	595	36/.051	36/.059	–	1.7	36000	868	659	24
91378	1.378	1.002	36/.084	36/.104	–	1.4	102000	2408	1810	42

NOTE All values are nominal



A Typical Compound Cable With Unique Features Stock #90680

From: Electromechanical Oceanographic Cables and Electrical Underwater Connectors, The Rochester Corporation, Culpepper, Virginia, 1975

TABLE 28b. CUSTOM DESIGNED OCEANOGRAPHIC CABLES
ELECTRICAL CHARACTERISTICS

Total # Conductors	Stock #	OD In.	No. Cdr	Cdr. AWG – Str.	Insul. Thk/Mtl. – In.	Core Belt – In	DC Res/1000 Cdr. Ohms	DC Res/1000 Shield	Cap. uufd/ft.	Z_0 Ohm	Att. db/1000	Freq. MHz	Special Feature Application
3	30300	.300	3	22-7 Coax	.013 PP	015	16		58	33			N00-PD-0870
				#38 Br Shd	None	PE	6						Magnetometer cable
5	50519	.523	2	16-19	.019 PP	040	4.5		41	–			Faired
			3	22-7 Coax	011 PP	PU	16.0	7	66	50			Oceanographic
3	60580	.593	3	20-7 Coax	.040 PE	-	10		34	50	4.1	1	Weighted Oceanog
				24w Serv Shd	.011 PE		1.8				1.2	.1	"Nixie"
8	80302	.302	7	22-7	.014 PP		16	–	39	–			Instrument Tow
			1	18-7	.019 PP		6.6	–	33	–	–	–	
8	80464	.464	2	12-19	.027 PE	–	1.92		75				Transducer Mooring
			6	20-7	.014 PP		10.5		65				
9	90347	.347	8	22-7	.011 PP	.012	16	–	46	–	–	–	Ribbon Fairing
			1	18-7	.020 PP	Ht	6.6	–		–			Antenna Buoy Tow
9	90463	.463	3	18-7 Coax	.020 PP	–	6.6	3.4	57	35	6.1	1	Instrument Tow
			3	22-7	.021 PP	–	16.0	–	39		1.7	1	Side Scan Sonar
11	90552	.552	1	24-19 Coax	.064 PE	.030	27		22	75	2.8	1	TV Camera
			10	18-7	.015 PP	PU	6.5						Pipe Inspection
10	90645	.645	4	24 TSP	.011 PP	.045	28		27		15	1	Deep Tow
			1	22-7	.040 PE	PU	19	–	30		9.4	.5	Seismic
			1	20-7	.027 PP		11	–			5	.1	
13	90653	.653	4	22-7 TSP	.011 PP	.035	16				17	5	Ribbon Faired Tow
			5	20-7	.015 PP	PP	11						Cable
15	90667	.667	6	14-19	.022 PP	.038	2.9		25		.5	.015	Tow Acoustic
			6	20-7	.018 PP	Ht	10		16				Device
			3	18-7	.027 Tz		7						
12	90680	675	3	14-19	.027 PE	040	2.9		46				Faired Oceanographic
			3	22-7 Coax	020 PE	PU	16.0	4.1	46	34	6.1	1	Buoy Mooring
			3	22-7	011 PE		16.0		26				
9	90688	688	3	10-19	026 PP	030	1.2		60		2.8	1	Ribbon Fairing
			1	22-7 Coax	.035 PP	Ht	16	3.2	31	50	1.7	.1	
			5	20-7	016 PP		10		32		.5	.01	
[illegible]	[illegible]	786	34	22-7	.011 PP	.040	16.0	4	55	–	–	–	Sonar Tow Cable
			1	9-19	.024 PVC	PU	9						
[illegible]	90788	788	[illegible]	20-19 Triax	.042 PP		12	11	30	53	4.2	1	Underground
			8	16-19	.028 PP		4.8	5.9			1.6	.1	Geophysical Logging
			4	20-19 Coax	.016 PP		12.8	6.4	57	28	1.2	.01	Cable
[illegible]	90812	.812	11	20-7 TSP	.014 Tz	.030	11.0	6	36	–	–	–	Water Blocked
				20-7 Drain		Tzl							Hi-Temp Geothermal
				A1 Myl Shd									Well Logging
24	90815	.815	3	20-7 Coax	.044 PE	.045	10	2.3	32	50			
			18	20-7	.018 PE	PP	10						
29	91378	1.378	4	12-7	.044 PP		1.7						
			5	20-7	.018 PP		10						
			1	Brd shd	.060 PP			1.2					
			10	#18 TSP	.020 PP		6.6						

NOTE All values are nominal. Detailed design sheets available on request.

From: Electromechanical Oceanographic Cables and Electrical Underwater Connectors, The Rochester Corporation, Culpepper, Virginia, 1975

TABLE 29. SPECIFIC GRAVITY OF MATERIALS USED IN EM CABLES, ROPES AND CHAIN

Material	Specific Gravity	Use
Metals:		
Steel; rolled and IPS	7.85	Chain, wire rope, EM cable braids
; armour wire	7.80	EM cable armour
Stainless Steel 302, 304, 305, 316; wire	8.02	Wire rope, EM cable braids
Iron; wrought bar	7.77	Chain
Copper; wire	8.92	EM cable conductor
Aluminum; hard drawn wire	2.70	EM cable conductor
Lead; sheathing	11.38	EM cable shield
Synthetic Fibers:		
Kevlar 29	1.44	Line, EM cable strength member
Kevlar 49	1.45	Line, EM cable strength member
Nylon	1.14	Line
Polyester	1.38	Line, EM cable braids
Polypropylene	0.90	Line, EM cable, wire rope core and jacket
Glass E	2.55	EM cable strength member
Glass S	2.50	EM cable strength member
Natural Fibers:		
Manilla	1.38	Line, wire rope core
Jute; dry fillers	0.50	EM cable
; treated fillers	0.63	EM cable
; asphalted serving	1.70	EM cable
Cotton; dry braid	0.60	EM cable
; weatherproof braid	1.40	EM cable
Extruded Plastics:		
Hypalon	1.12-1.28	EM cable jacket, insulation
Nitrile Rubber	0.98-1.10	EM cable jacket
Neoprene	1.23-1.25	EM cable jacket
Nylon	1.07	EM cable jacket
Polyethylene; low density	0.92	EM cable insulation
; high density	0.95	EM cable insulation
Polyurethane	1.06	EM cable, wire rope, and line jackets
PVC	1.2 -1.5	EM cable, insulation
Kynar	1.85	EM cable, insulation
Teflon	2.20	EM cable, insulation
Flexible Foams:		
Urethane; compressible	0.50	EM cable buoyant jackets
; non-compressible	0.58	EM cable buoyant jackets

STRESS-STRAIN CHARACTERISTICS

The stress-strain characteristics of the tension member are especially significant inputs to the static and dynamic calculations of cable structure behavior. C and k are input from:

$$E = (T/C)^k \quad \text{where } E = \text{Strain or \% elongation}$$
$$T = \text{Tension}$$
$$C = AE$$

If k = 1 then the material behaves linearly and AE (the slope of the load vs % elongation or strain) curve is constant. AE is the product of cross sectional area of the load bearing portion of the member times E, the modulus of elasticity of the composite load bearing member. As an alternative to entering AE the actual tension and strain curve may be entered with the user specifying the number of tension and strain data pairs to be entered to define the curve.

In general the preliminary analysis may be carried out by assuming a linear stress-strain behavior of the member at the estimated load level. To do this one chooses a tension member and then expresses the estimated loads on it as a percentage of the member's breaking strength. The AE at that load level may then be obtained from the tables in this section and used to complete the analysis.

If the member is too elastic to safely assume a linear behavior over the probable load range then the tension - % elongation curve for that particular range of loads is required. This type of elastic behavior is usually confined to synthetic lines (excluding Kevlar) with a widely varying load due to dynamic loading.

Wire Rope

Table 30 lists the E for various wire rope constructions at load levels expressed as percent of breaking strength. Table 31 lists the approximate metallic area of most of these same ropes to permit determination of AE.

For example, assume we were designing a system which had an estimated 10,000 lbs of tension and we decided to use a factor of safety of 5 and 6 x 19 IWRC wire rope. From Table 4 we would choose 3/4" diameter rope in any of the three grades in which it is offered. The load level for these three grades would differ (20%, 17%, and 15%) due to different breaking strengths. Progressing to Table 3d, we see the E to use would be 13.5×10^6 for the higher grades and either 13.5 or 15×10^6 for the low grade 6 x 19. The cross-sectional metallic area of 3/4" 6 x 19 IWRC obtained from Table 31 is 0.26 in^2. AE for the high grade wire ropes is thus $0.26\ in^2 \times 13.5 \times 10^6\ lbs/in^2 = 3.51 \times 10^6$ lbs.

TABLE 30. APPROXIMATE MODULUS OF ELASTICITY OF WIRE ROPES FOR VARIOUS PERCENTAGE LOADS WITH RESPECT TO BREAKING STRENGTH

Rope Construction	Modulus of Elasticity (psi x 10^{-6})		
	0-20% BS	20-65% BS	80% BS
6x7 Fiber Core	11.7	13.0	——
6x19 Fiber Core	10.8	12.0	——
6x37 Fiber Core	9.9	11.0	11.0
8x19 Fiber Core	8.1	9.0	——
6x19 IWRC	13.5	15.0	——
6x37 IWRC	12.6	14.0	——
3x19	——	——	21.8
3x46	——	——	20.0
7x7 Stainless Steel	——	——	13.7
7x7 Titanium	——	——	8.6

TABLE 31. APPROXIMATE METALLIC CROSS-SECTIONAL AREA OF WIRE ROPES

Rope Diameter (in)	Cross-Sectional Metallic Area (in^2)				
	6x7 FC	6x19 FC 6x37 FC	6x19 IWRC 6x37 IWRC	8x19 FC	3x19
1/4	.024	.025	.029	.022	.027
5/16	.037	.039	.045	.034	.042
3/8	.054	.046	.065	.049	.060
1/2	.095	.10	.12	.088	.11
5/8	.15	.16	.18	.14	.17
3/4	.21	.23	.26	.20	.24
7/8	.29	.31	.35	.27	.33
1	.38	.40	.46	.35	.43
1 1/8	.48	.51	.58	.44	.54
1 1/4	.60	.63	.72	.55	——
1 3/8	.72	.76	.87	.66	——
1 1/2	.86	.90	1.0	.79	——
1 3/4	——	1.2	1.4	——	——
2	——	1.6	1.8	——	——
2 1/2	——	2.5	2.9	——	——
3	——	3.6	4.1	——	——

From: Containerized Cable Stowage, TR71-05, Naval Ship Systems Command Contract Report N00024-70-6-5474, March 1971

Synthetic Fiber Ropes

The stress-strain behavior of most synthetic fiber ropes are non-linear and thus AE varies as a function of the applied load. Table 32 supplies a method of determining the strain or AE on various double braided lines given the tension and nominal line diameter. Table 33 lists load dependent AE/BS values for some synthetic lines manufactured by Samson Ocean Systems, Inc. under various types and levels of loading. As an example use Table 33 to determine the AE of 1" diameter double braided nylon line at 6,000 lbs tension and cyclic loading in water. From Table 16 we find the breaking strength (BS) of 1" nylon to be 33,600 lbs. That makes the loading, $\frac{6,000}{33,600} \times 100$ or 18% of BS. Under wet, cyclic loading we find $\frac{AE}{BS} = 2.5$ for 15% BS load and 3.23 for 20% BS load. Interpolating gives $\frac{AE}{BS}$ at 18% = 2.94. Finally AE = 2.94 BS = 2.94 (33,600) = 9.88×10^4 lbs.

If the probable range of loads does not justify assumption of a linear behavior then the tension and % elongation values must be input. These curves are sometimes included in catalogs but generally do not specify the types or conditions of loading. Tension - % elongation curves are available from manufacturers of synthetic lines for the particular line construction and composition.

Aramid (Kevlar) ropes are constructed of yarns consisting of filaments. A typical yarn used in rope and cable strength number construction is 1,500 denier yarn. 1,500 denier means the yarn weighs 1,500 grams for a 9,000 meter length. A 1,500 denier yarn consists of 1,000 filaments, each 12 microns (.00047 in) in diameter. Thus the A of 1,500 denier yarn is given

by:

$$A_{1500} = 1{,}000\ \pi\ \frac{(.00047\ \text{in})^2}{4} = 1.73 \times 10^{-5}\ \text{in}^2$$

The E of Kevlar 29 yarn is 12×10^6 lbs/in^2 and Kevlar 49 is 19×10^6 lbs/in^2. The AE of individual yarns may thus be calculated. To calculate the AE of the rope the number of yarns (or 'ends') is multiplied by A of the yarn to obtain the load bearing area. The E of the rope will vary depending on the type of construction, being fairly close to yarn E for parallel fiber ropes and considerably less for cable laid and braided ropes.

It should be noted that recent tests have indicated that the AE of synthetic rope is dependent on the period of the dynamic load cycle. While conclusive numerical results are not yet available, this dependence is sufficiently significant to warrant caution in applying AE values by present practices.

TABLE 32

NON-LINEAR STRAIN OF DOUBLE BRAIDED* LINE

Let T = Line tension in lb

D = Nominal diameter in inches

e = Strain of line

$$e = \frac{T}{AE}$$

$$AE = aD^2 + bT$$

OUTER BRAID	INNER BRAID	a lb /in²	b
Nylon	Nylon	32,200	2.568
Nylon	Nylon	72,400	-0.811
Polyester	Polypropylene	58,500	2.454
Polypropylene	Polypropylene	67,800	-1.406

* Samson Cordage Works, Boston, Massachusetts

From: A Short Compendium of the Physical Properties of Mooring Line Components, CR80.0020, Civil Engineering Laboratory, Naval Construction Battalion Center, May 1981

Table 33. AE/BS for various Samson Synthetic Lines Under Various Load Levels and Loading Conditions

MATERIAL	DESCRIPTION	AE/BS for Various % BS					
		10% BS	15% BS	20% BS	25% BS	30% BS	35% BS
2 in 1 Nylon double braid Nylon	dry, cyclic loading	2.99	3.41	3.48	4.03	4.51	4.90
	wet, cyclic loading	1.87	2.50	3.23	3.91	—	—
	dry, static loading	1.59	2.38	2.67	3.21	3.75	4.38
	wet, static loading	1.30	1.95	2.35	2.63	3.19	3.57
Stable Braid double braid Polyester	wet or dry; cyclic loading	10.00	10.00	10.00	10.00	10.00	10.00
	wet or dry, static loading	4.35	4.69	4.69	4.69	4.69	4.69
KEXLON double braid Polyester cover/Kevlar core	stabilized cyclic load	20.0	31.9	47.6	53.2	62.5	87.5
	new static load	8.33	12.4	17.0	21.2	26.6	29.7
VLS/DURON single braid Polyester	static loading	7.14	8.29	9.05	9.51	12.1	12.9
	cyclic loading	11.0	12.0	12.7	13.2	13.6	14.0
DURON XLS	static loading	6.06	6.98	8.70	10.0	11.2	12.4
	cyclic loading	10.0	11.8	13.3	15.1	17.2	21.3
2 in 1 NYSTRON double braid Nylon/Polyester composite	dry, cyclic loading	3.60	4.32	5.06	6.25	7.36	8.75
	wet, cyclic loading	2.65	3.37	4.15	4.88	5.38	6.83
	dry, static loading	2.67	3.33	3.83	4.50	5.06	5.38
	wet, static loading	2.03	2.58	3.03	3.37	3.65	—
N-12 single braid Polypropylene	cyclic loading	5.56	7.14	7.94	9.29	10.1	10.7
	static loading	2.44	2.97	3.31	3.57	3.80	—
MFP 2 in 1 double braid multi filament Polypropylene	cyclic loading	4.81	5.70	6.67	7.81	8.50	8.88
	static loading	2.35	2.74	3.14	3.46	3.87	—
POWER BRAID double braid Nylon cover/MFP core	dry, cyclic loading	3.51	4.23	5.06	5.78	6.56	7.65
	wet, cyclic loading	2.35	3.37	4.30	5.26	6.22	6.67
	dry, static loading	4.82	6.00	7.27	8.77	10.2	11.7
	wet, static loading	3.28	4.62	5.84	7.58	8.45	8.86

Calculated from load-elastic elongation curves supplied by Mr. Randy Longerich, Samson Ocean Systems - Average behavior curves were used for above values

Chain

Table 34 lists formula for estimating the AE of stud link and open link chain. The stress-strain behavior of stud link chain is close to linear due to the stud preventing deformation of the link at higher loads. Open link chain can be treated similarly as long as the loading is below the proof load limit. Beyond that point the chain begins plastic deformation which changes the stress-strain behavior.

TABLE 34

ELASTICITY OF STEEL CHAIN

1. Forged Steel[1] Stud Link	$AE = 8.595\ D^2 \times 10^6$ lb
2. Proof Coil[2] Open Link	$AE = (2.827\ D - 0.16) \times 10^6$ lb

E = Young's Modulus, psi

D = Side Wire Diameter, Inches

k = Spring Constant = AE/L

1 "The Elasticity of Stud-link Chain in Tension, Baldt Anchor, Chain and Forge Division, The Boston Metals Company

2 Based on stress-strain curves for 3/8, 1/2, 5/8, and 3/4 inch chain samples provided by Mr. E.J. Crook, Vice President, Engineering, The Crosby Group, American Hoist and Derrick Company in a personal correspondence

From: A Short Compendium of the Physical Properties of Mooring Line Components, CR80.0020, Civil Engineering Laboratory, Naval Construction Battalion Center, May 1981

Electromechanical Cables

EM cables are constructed such that the strength member carries most of the tension applied to the cable. For the purpose of determining stress-strain behavior it is assumed all load is carried by the strength member. External strength members are usually steel armour wires. Table 35 lists the wire sizes and diameters normally used in larger cable, Tables 25, 26, 27 and 28a used earlier in this report give wire diameters and the number of wires used in the stock Rochester EM cables. AE for these types of cables may be approximated by multiplying the metallic area of the armour wires times E for the cable. E for the cable may be approximated as 0.7E of the wire due to structural elasticity of the composite cable. This approximation will vary considerably depending on the actual cable construction and load level and should be used only for preliminary analysis.

TABLE 35

STEEL ARMOR WIRE

BWG Size	Diameter Inches	Approx. Air Weight lbs/1000 feet	Approx. Weight in Sea Water lbs/1000 feet	Approx. Breaking Strength (lbs.) Based on 100,000 psi
0	.340	313	272	9079
1	.300	244	212	7068
2	.284	218	189	6335
3	.259	182	158	5268
4	.238	153	133	4449
5	.220	131	114	3801
6	.203	112	97	3237
7	.180	87	76	2545
8	.165	74	64	2138
9	.148	60	52	1720
10	.134	49	43	1410
11	.120	39	34	1131
—	.112	33	29	985
12	.109	32	28	933
13	.095	25	22	709
—	.086	20	17	580
14	.083	19	16	541
15	.072	14	12	407
16	.065	11	10	332

From: Manual for Submarine Cables, Hydrospace Systems Division, Simplex Wire and Cable Company, 1968

SECTION III
HYDRODYNAMIC INPUTS TO CABLE ANALYSIS

DRAG COEFFICIENTS ON UNFAIRED CABLES

Normal Drag, C_D

Table 36 lists normal drag coefficients for typical unfaired surfaces of cable, wire ropes, and synthetic lines. The range of Reynold's Number, R_n for which C_D is given covers the usual range experienced by cable structures in sea water and air. These coefficients do not include the effect of strumming which can increase the effective C_D up to 2.5 times as illustrated by Figure 1.

Figure 2 plots available drag coefficient data for open link and stud link chain. The effective diameter used to calculate R_n is the outside width of a link. This width data is included in Tables 20 and 21 in Section II. Note that the range of Reynolds Numbers, for which data on C_D is available, is not extensive. Over the range of R of 1.07×10^5 to 3.45×10^5 the C_D values for stud link chain averaged 0.82 with a maximum of 0.99 and a minimum of 0.60. A range of R_n from 1.4×10^4 to 1.09×10^5 with open link chain resulted in an average of 0.87 with a maximum of 0.96 and a minimum of 0.70.

<u>Tangential Drag, C_t</u>

Figure 3 illustrates typical tangential drag, C_t coefficients for various wire rope, cable, and synthetic line constructions. As can be seen from the figure, C_t is low compared to C_D, the values in the figure being less than .02. Figure 4 is the result of tow tank experiments conducted to obtain C_t for open link chain in the range of $10^4 < R_n < 1.5 \times 10^5$. An average value of $C_t = .083$ seems to hold over most of this range.

TABLE 36

NORMAL DRAG COEFFICIENTS FOR CABLES

Cable (1)	REYNOLDS NUMBER RANGE 10^3-10^4 Minimum (2)	Average (3)	Maximum (4)	Number of tests (5)	10^4-10^5 Minimum (6)	Average (7)	Maximum (8)	Number of tests (9)
Unjacketed stranded steel cable	0.98	1.54	2.47	65	0.30	1.29	3.60	115
Smooth jacketed steel cables	1.16	1.50	1.64	11	0.72	1.14	1.78	24
Synthetic line:								
Braided	1.11	1.14	1.15	3	1.11	1.14	1.16	5
Plaited	0.79	1.17	1.64	15	0.88	0.99	1.15	78

From: Undersea Suspended Cable Structures, Nordell, N.J., and Meggitt, D.J., Journal of the Structural Division, ASCR, Vol. 107, No. ST6, June 1981

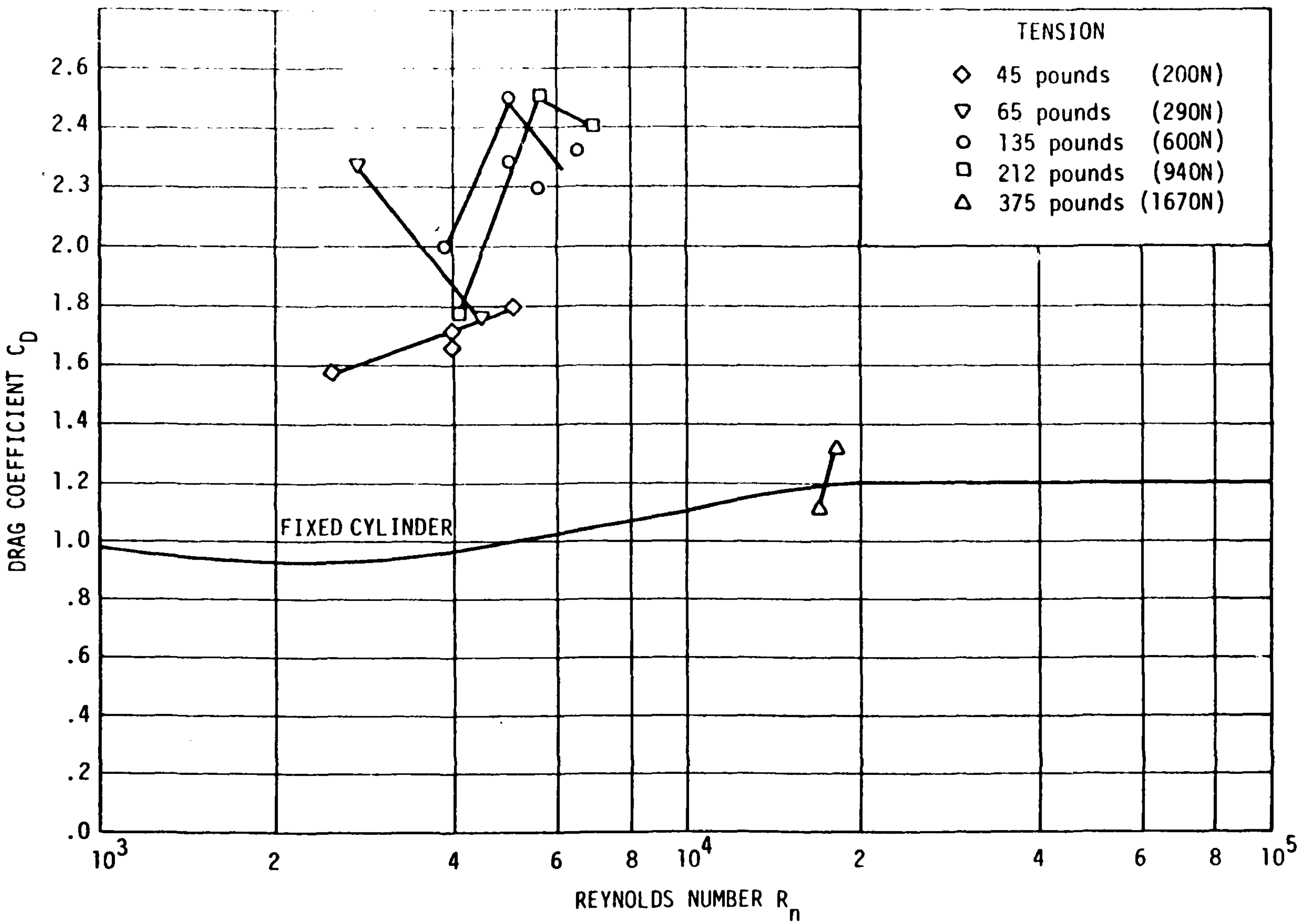


Figure 1. Drag Coefficient of Strumming 0.7-Inch (1.8 cm)-Diameter Cable

From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, Feb. 1977

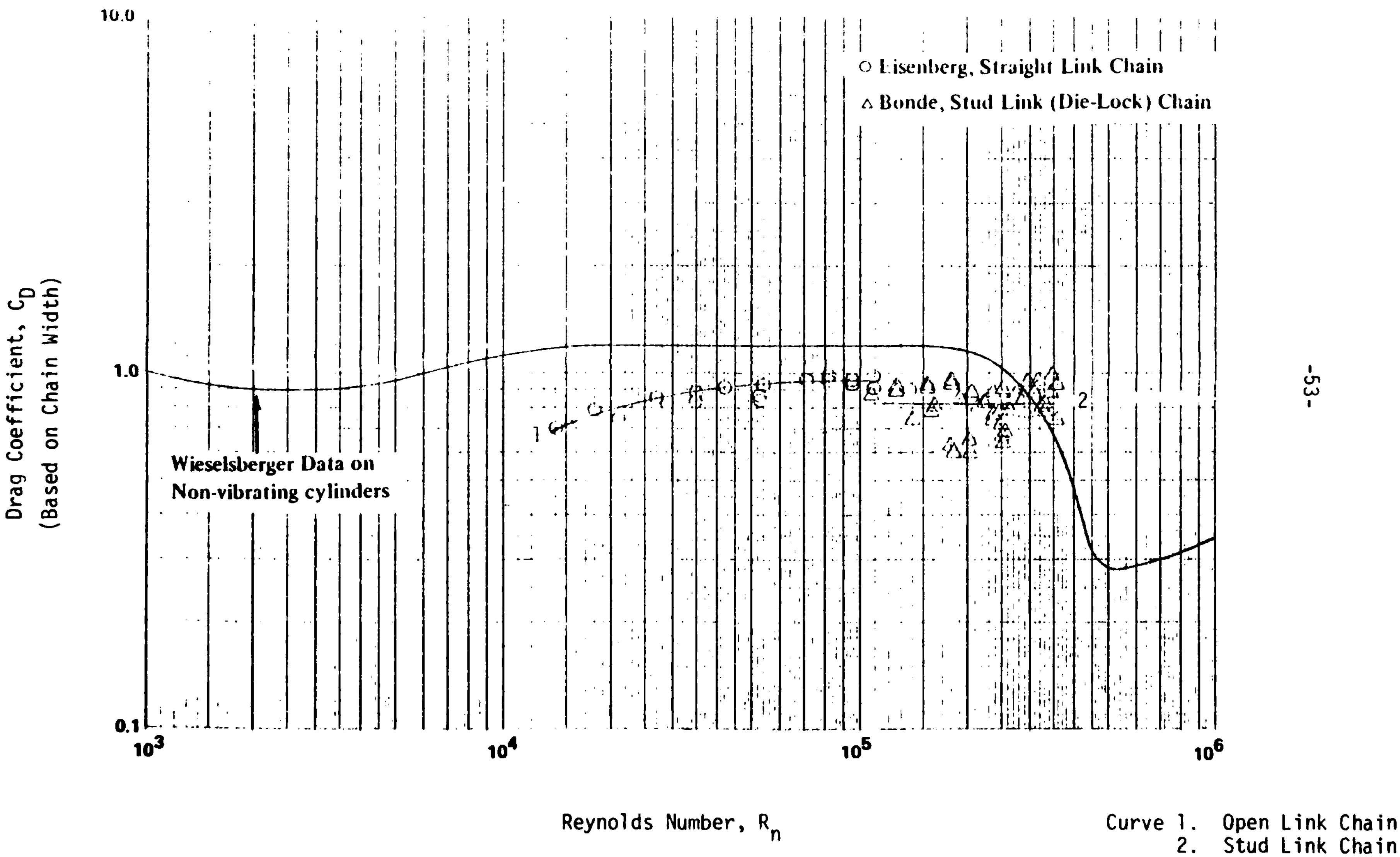


Figure 2. Summary of Drag Coefficient Data for Chain

From: A Survey of Available Data on the Normal Drag Coefficient of Cables Subjected to Cross Flow, CR78.001, Civil Engineering Laboratory, Naval Construction Battalion Center, August 1977

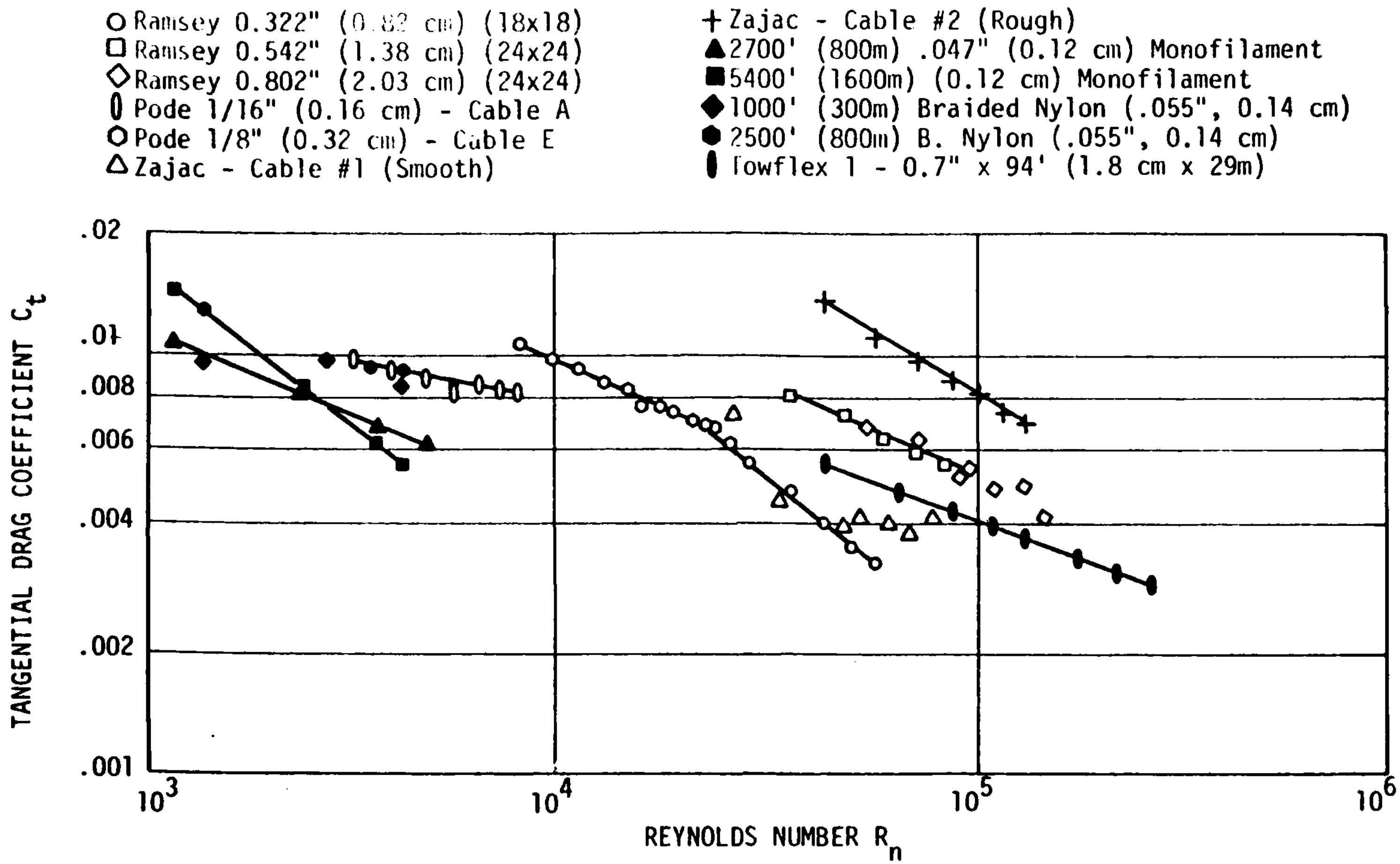
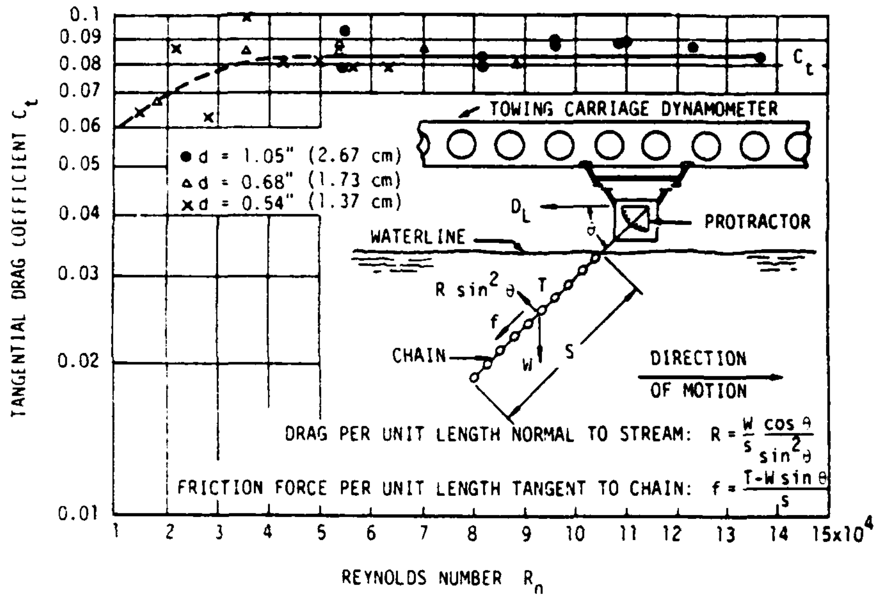


Figure 3. Tangential Drag Coefficient Versus Reynolds Number for Various Types of Cables

From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, Feb. 1977

Figure 4
Drag Coefficients for Commercial Straight-Link Chain



From: Characteristics of the NRL Mark 3 Boat Type Buoy and Determination of Mooring Line Sizes, Eisenberg, P., David Taylor Model Basin Report 550, September 1945

Drag Coefficients of Faired Cables

Figure 5 plots C_D versus R_n for various streamlined fairings which are free to swivel on the cable. These curves are the result of DTNSRDC experiments performed on the shapes illustrated and described in Figure 6. Additional tests results on trailing fairings are given in Figure 7 with shapes described in Table 37.

Figure 8 presents C_D and D_t for cable with a helical wrap of bare wire. Figures 10 and 11 give C_D for cables with fringe fairings at different tensions. Finally Figure 12 plots results of tests for C_D on helically wrapped fringe fairings.

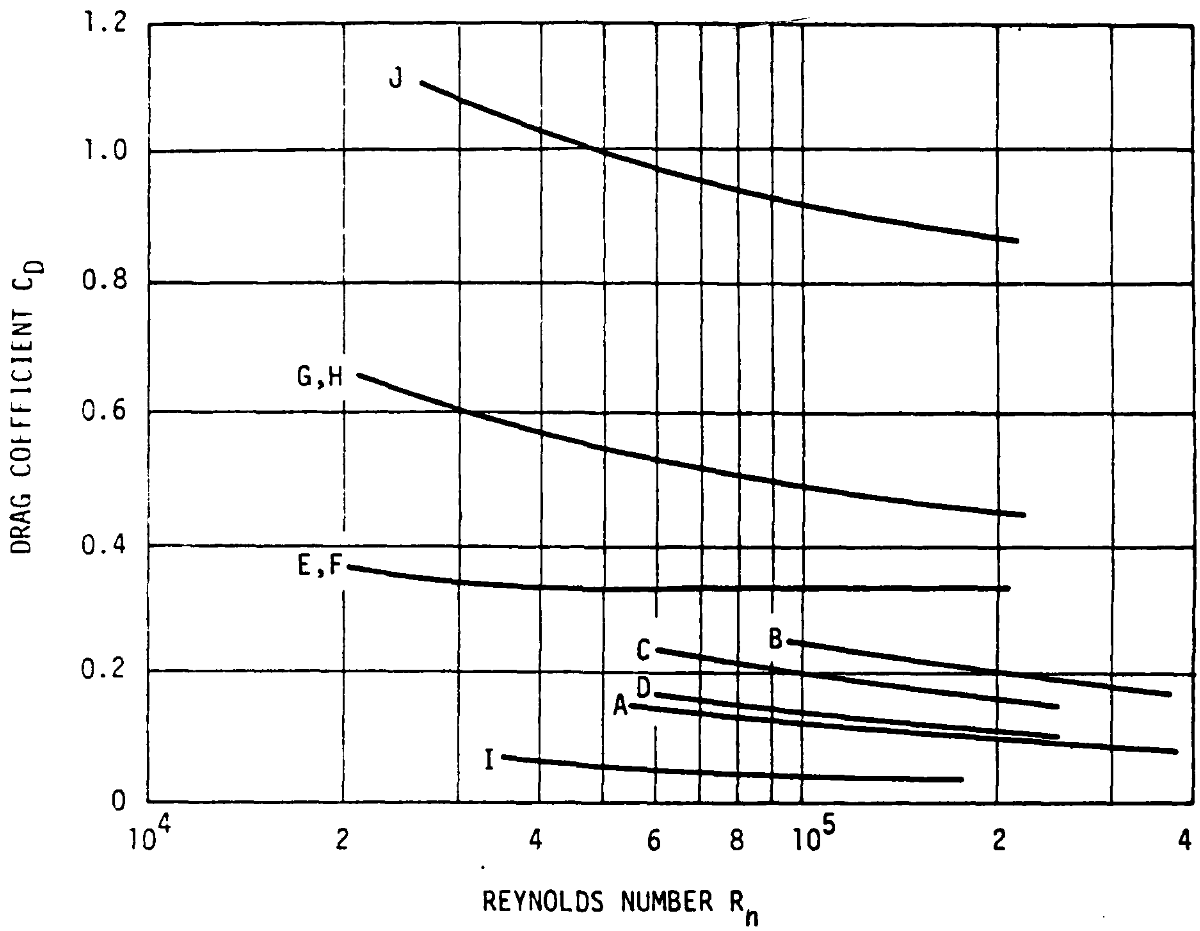
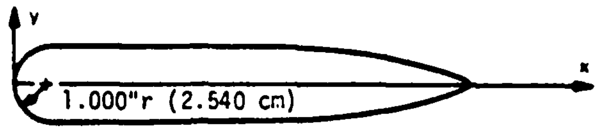


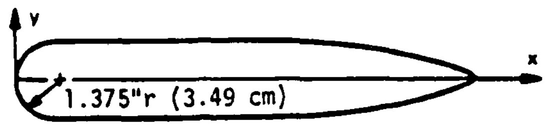
Figure 5

Drag Coefficient Versus Reynolds Number for Various Streamlined, Free Swiveling Fairing Models

From: "Experimental Determination of Hydrodynamic Loading for Ten Cable Fairing Models", Folb, R., DTNSRDC Report 4610, David Taylor-Naval Ship Research and Development Center, November 1975



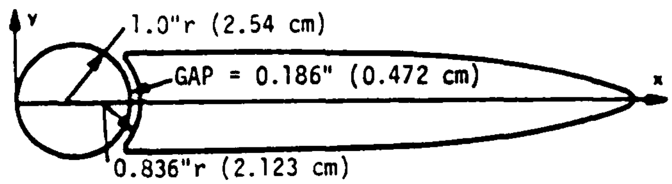
A. This represents fairings molded from rubbery materials with each segment about 50 cable diameters long. A metal conduit is molded in the nose to provide a free channel for the cable.



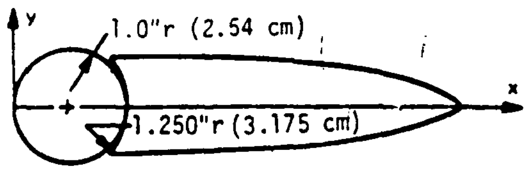
B. This represents fairings molded from rigid plastic in short sections about 3.5 cable diameters long. Each section has three parts: the plastic tail piece, a stamped metal nose piece, and a link to align the trailing edge of adjacent sections.

C. This is a modification of fairing B in which the gaps between the plastic tail pieces have been smoothly faired.

D. This is a further modification of fairing B, with the gaps between the metal nose pieces filled as well as the tail piece gaps.



E. The trailing piece of this fairing is molded, like Model A, from a long segment of rubbery material. It is attached to the cable by metal straps about 1 cable diameter wide at intervals of about 5 cable diameters, leaving the cable mostly exposed.



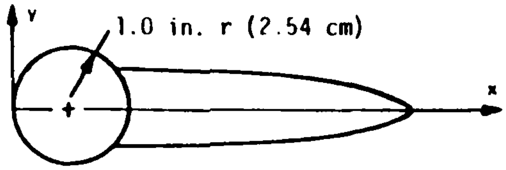
F. This trailing fairing has a shorter chord and smaller straps spaced farther apart than Model E. It has slightly less drag.

Figure 6

Description of Shapes Used to Obtain Curves in Figure 5

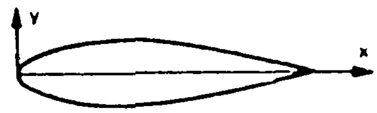
From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, Feb. 1977

From: A Short Compendium of the Physical Properties of Mooring Line Components, CR80.0020, Civil Engineering Laboratory, Naval Construction Battalion Center, May 1981

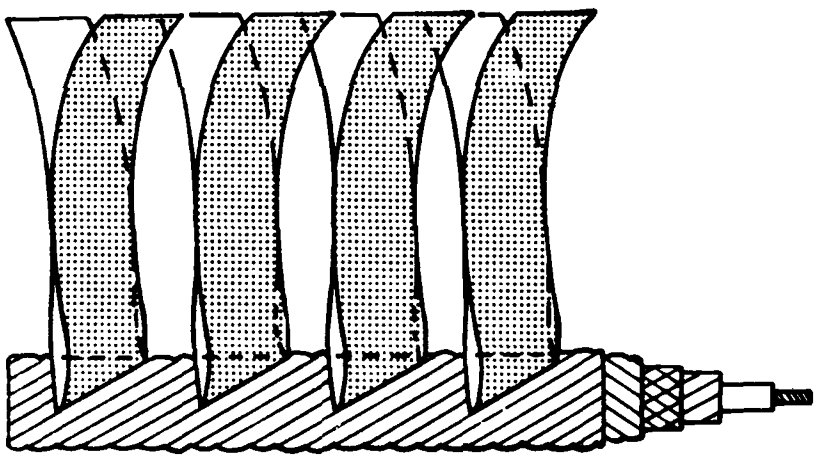


G. This trailing fairing model replaces the straps on Model E with wire clips whose diameter is 1/4 the cable diameter, spaced about 6 cable diameters apart. Both normal and tangential drag are greater than for Model E.

H. This trailing fairing follows the pattern of Model E. The chord/cable diameter is about 3.5, thirty percent less than for Model E, and the straps are 44 percent wider. The normal drag is substantially higher.



I. This fairing is a radical change from Models A through H. It is designed to have a torque-free (non-metallic) strength member integrally molded into its nose. The continuous smooth, streamlined outer shape gives very low drag.



J. This is not a streamlined fairing. Rubbery ribbons are threaded into the cable strands. They trail the wake, breaking up the energy-absorbing vortex street. Tests used a 2" diameter cable with 2.75" long, .0624" thick ribbons spaced 0.406" apart. Width of ribbons unspecified.

Figure 6 (continued)

From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, Feb. 1977

From: A Short Compendium of the Physical Properties of Mooring Line Components, CR80.0020, Civil Engineering Laboratory, Naval Construction Battalion Center, May 1981

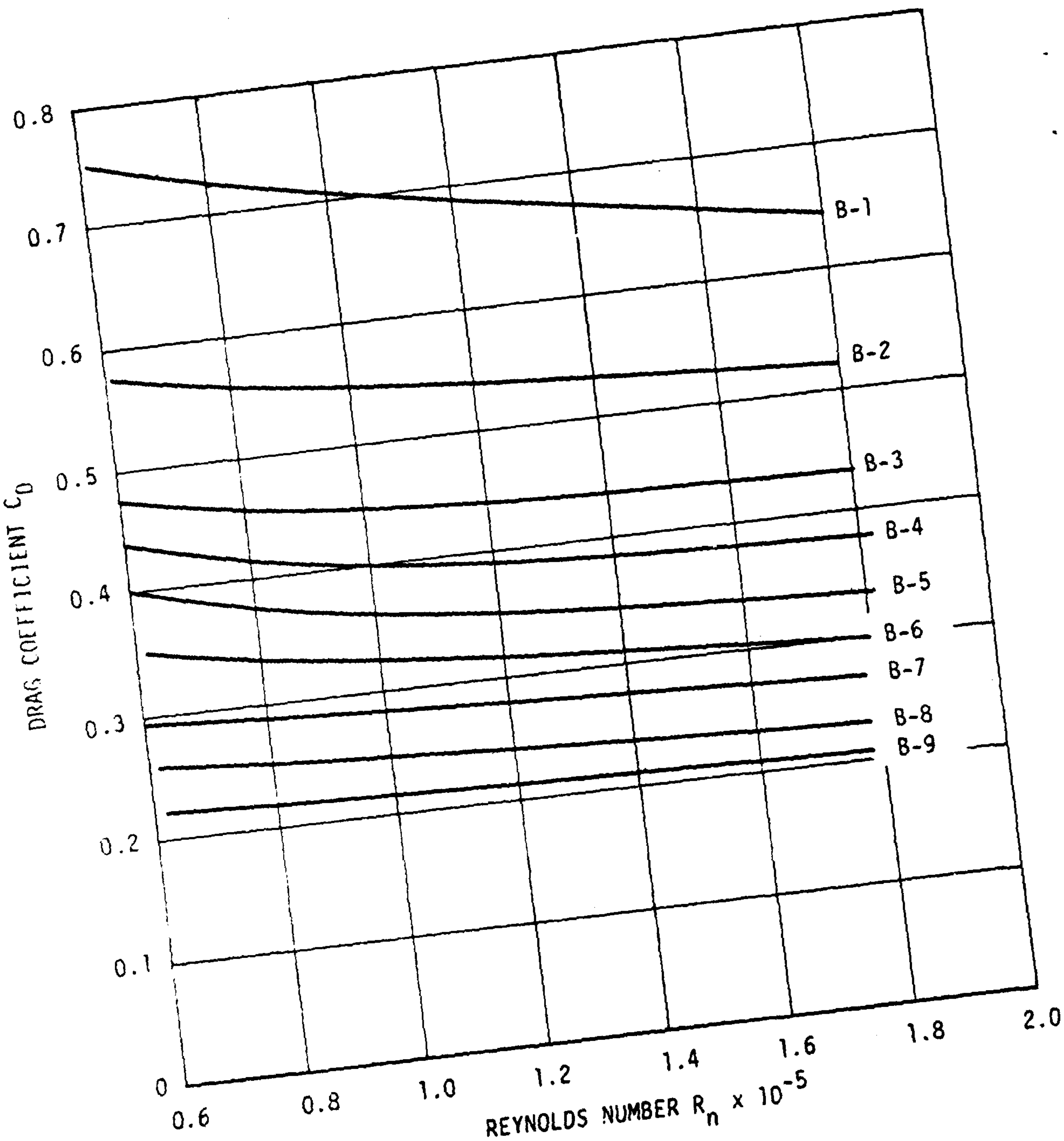
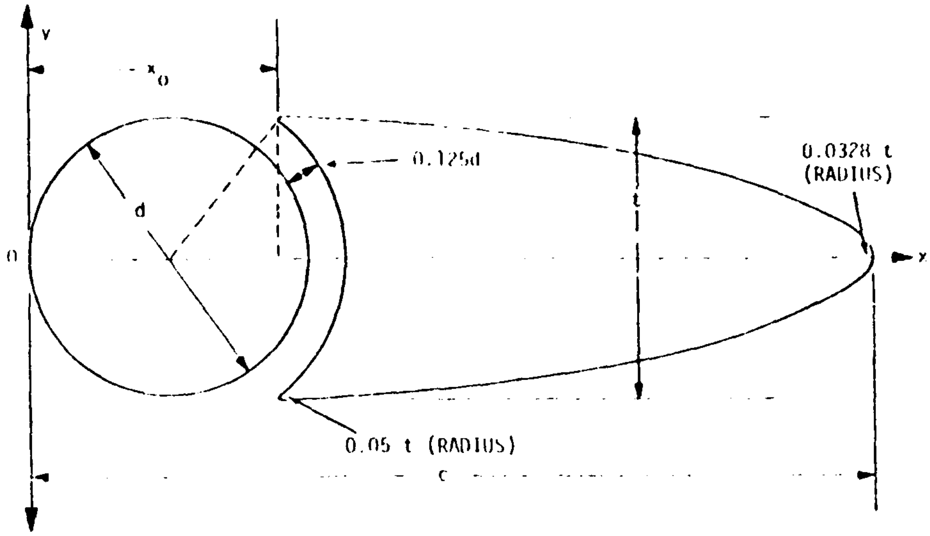


Figure 7

Drag Coefficients for TMB Series B Trailing Fairings

From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, Feb. 1977



Series B					
Designation	Thickness Ratio	Fineness Ratio c/t	Chord Length (ft)	Chord Length (cm)
B-1	0.6	2.875	0.28	8.5
B-2	0.6	3.875	0.38	11.6
B-3	0.6	4.875	0.47	14.3
B-4	0.8	2.875	0.28	8.5
B-5	0.8	3.875	0.38	11.6
B-6	0.8	4.875	0.47	14.3
B-7	1.0	2.875	0.28	8.5
B-8	1.0	3.875	0.38	11.6
B-9	1.0	4.875	0.47	14.3

TABLE 37. GEOMETRICAL PARAMETERS OF DTMB SERIES B SHAPES USED TO OBTAIN CURVES SHOWN IN FIGURE 7

From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, Feb. 1977

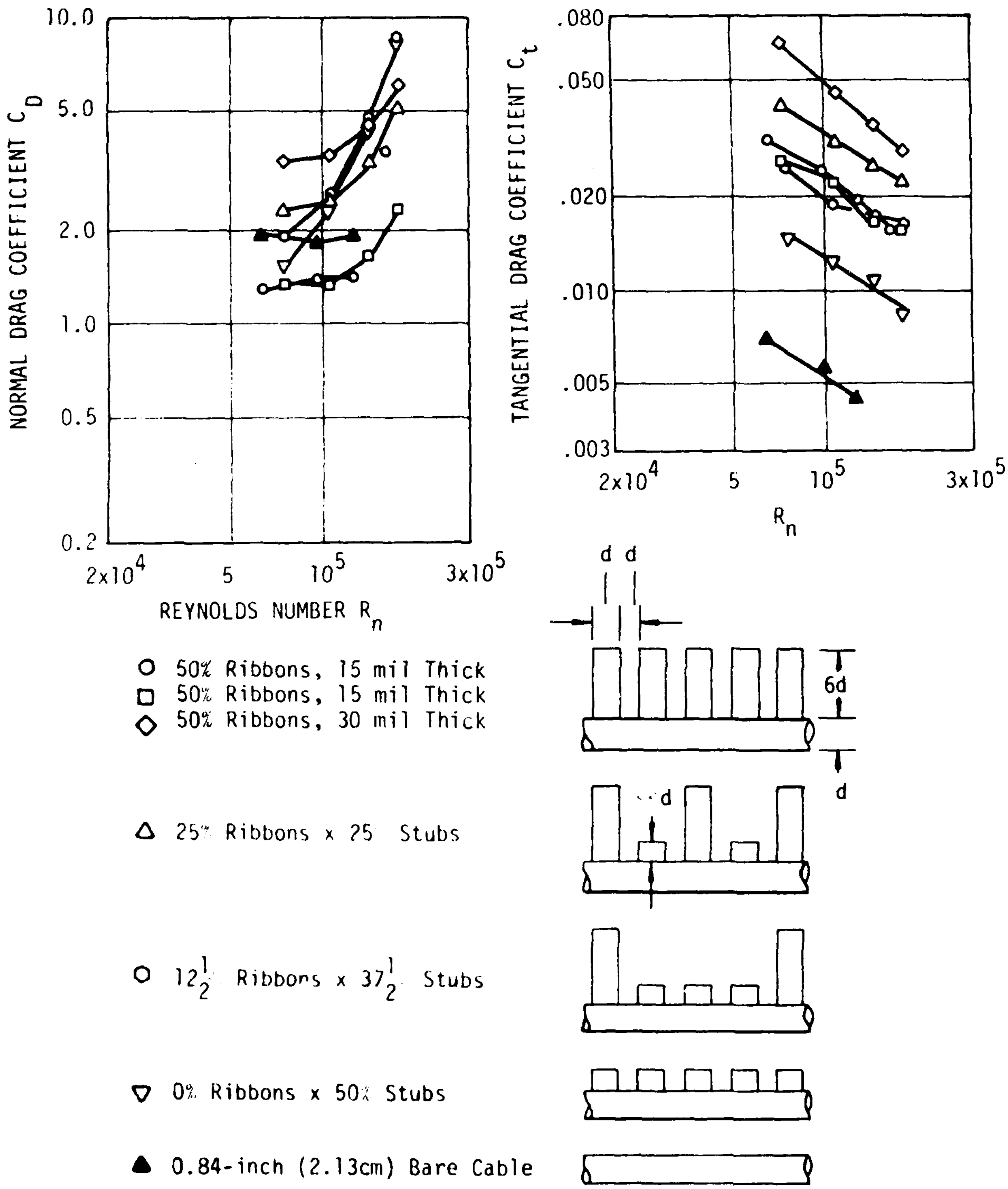
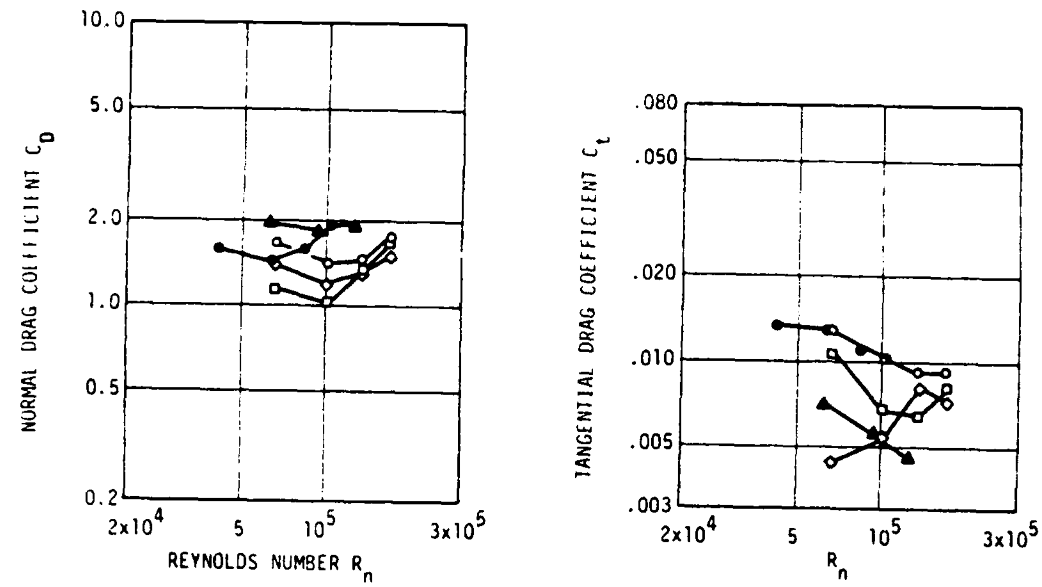


Figure 8

Hydrodynamic Coefficients for Ribbon Faired Tow Cables

Compared to Bare Cable

From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, Feb. 1977



Helical Wrap Basin & Sea Data

h/d = 0.23

- ● p/D = 15, Basin Data
- ○ p/D = 15, Sea Data
- □ p/D = 20, Sea Data
- ◇ p/D = 30, Sea Data
- ▲ 0.84-inch (2.13cm) Bare Cable Sea Data

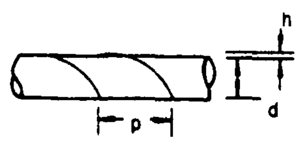


Figure 9

Hydrodynamic Coefficients for a Cable

With a Helical Wrap of Bare Wire

From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, Feb. 1977

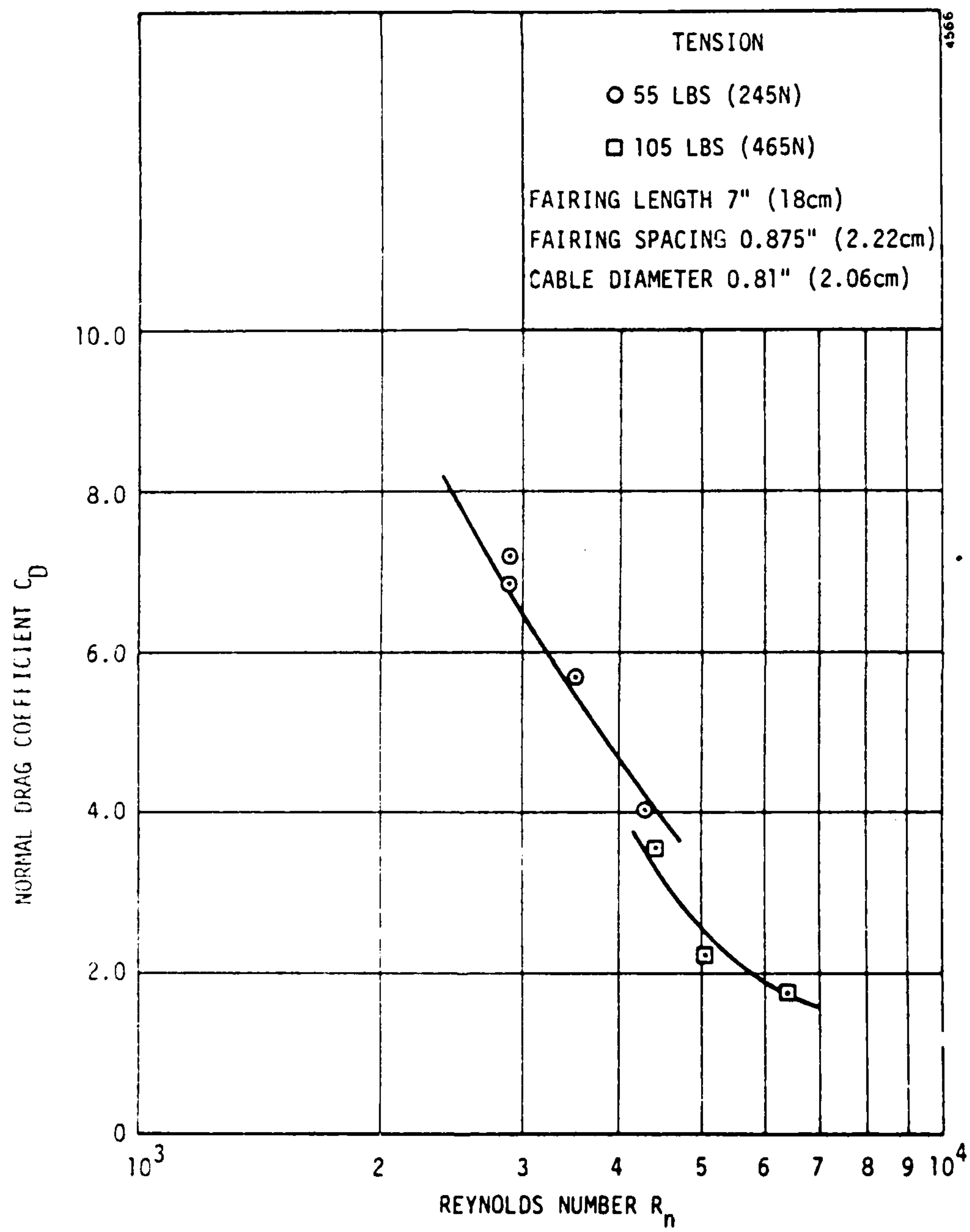


Figure 10

Drag Coefficient for Cable with Polypropylene Fringe Fairing

From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, Feb. 1977

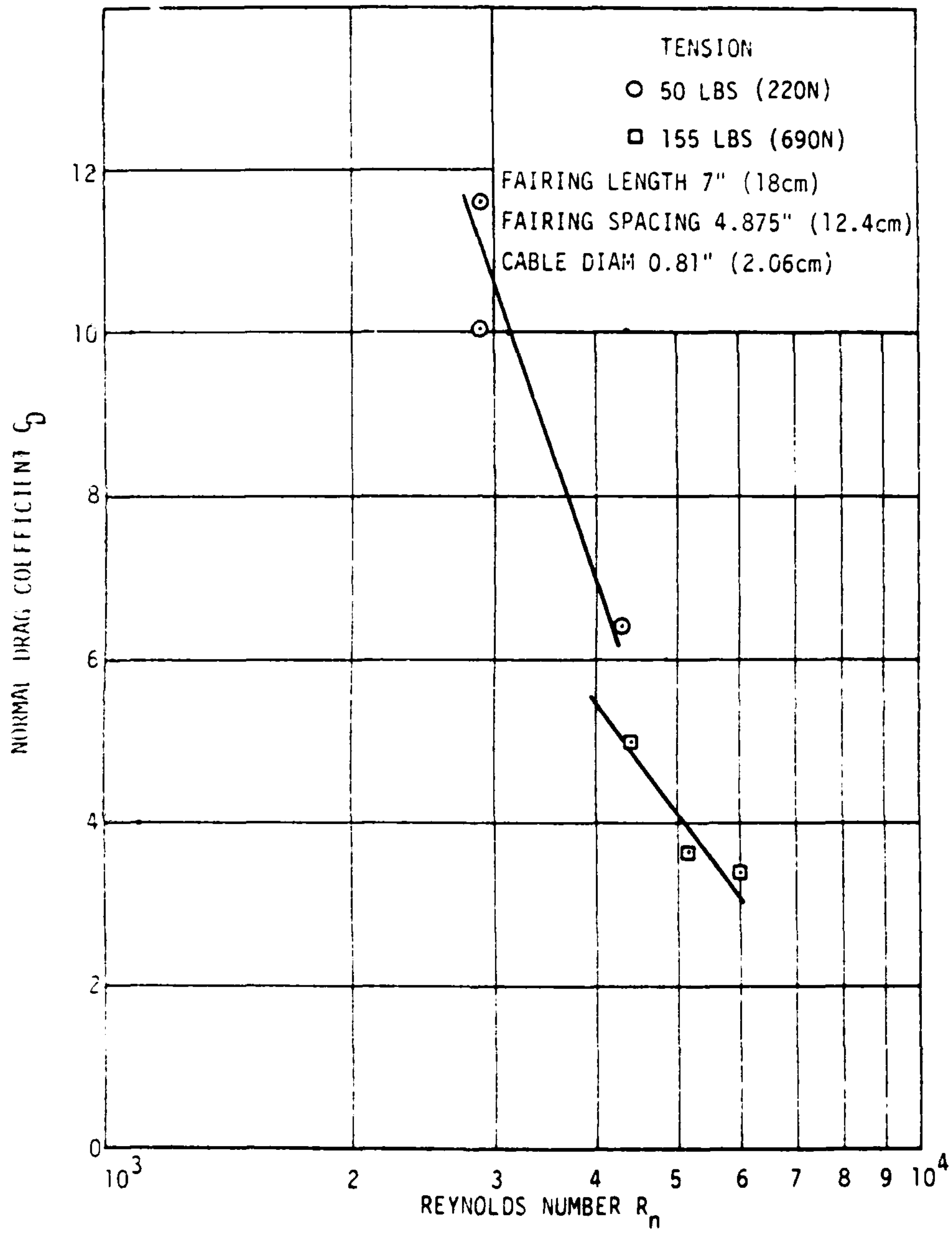
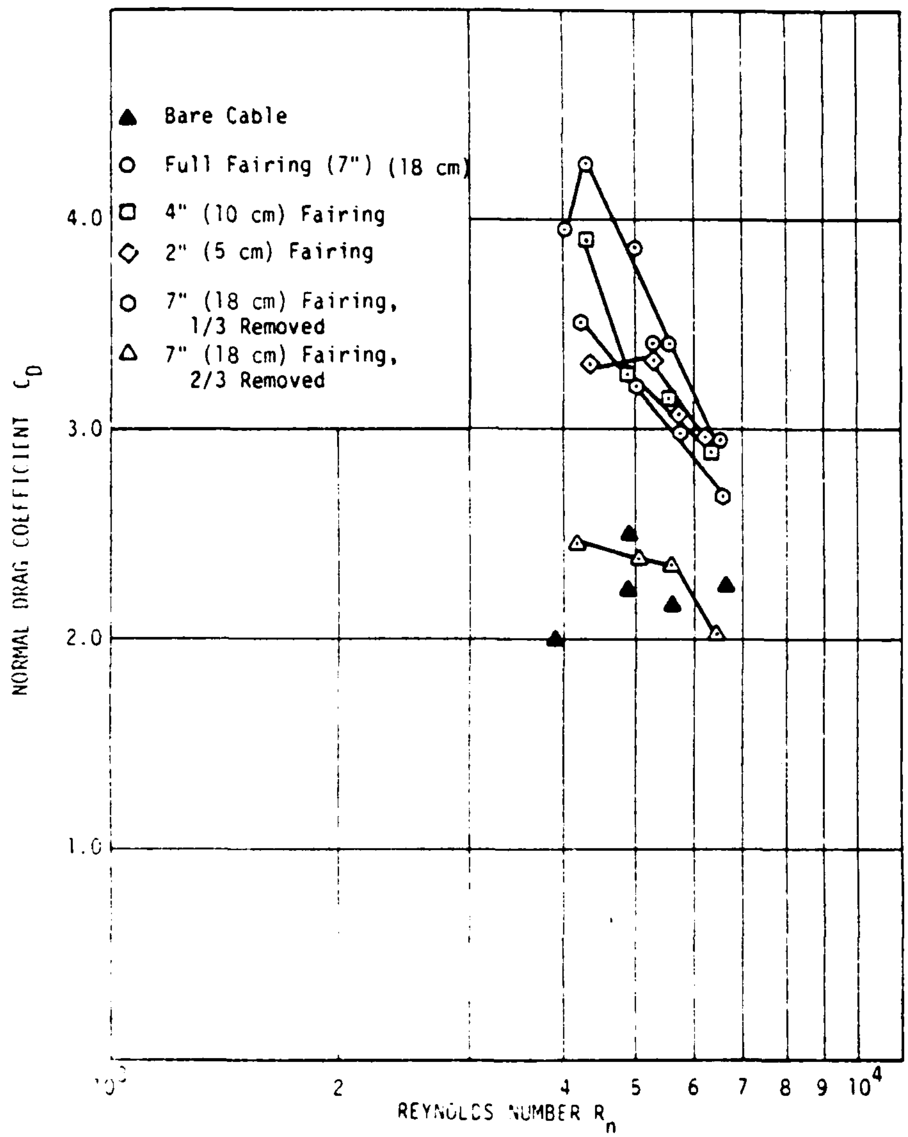


Figure 11

Drag Coefficient for Cable with Monofilament Fringe Fairing

From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, Feb. 1977



NOTE: Helically Wrapped
Fringe Fairing = Length 7 in. (18 cm), Spacing 0.875 in. (2.22 cm)
Pitch Ratio = 10
Fairing configurations are described in Table 3-6.

Figure 12

Drag Coefficients for Cable with Helically Wrapped Fringe Fairings

From: Handbook on Hydrodynamic Characteristics of Moored Array Components, FPO-1-77(9), Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, Feb. 1977